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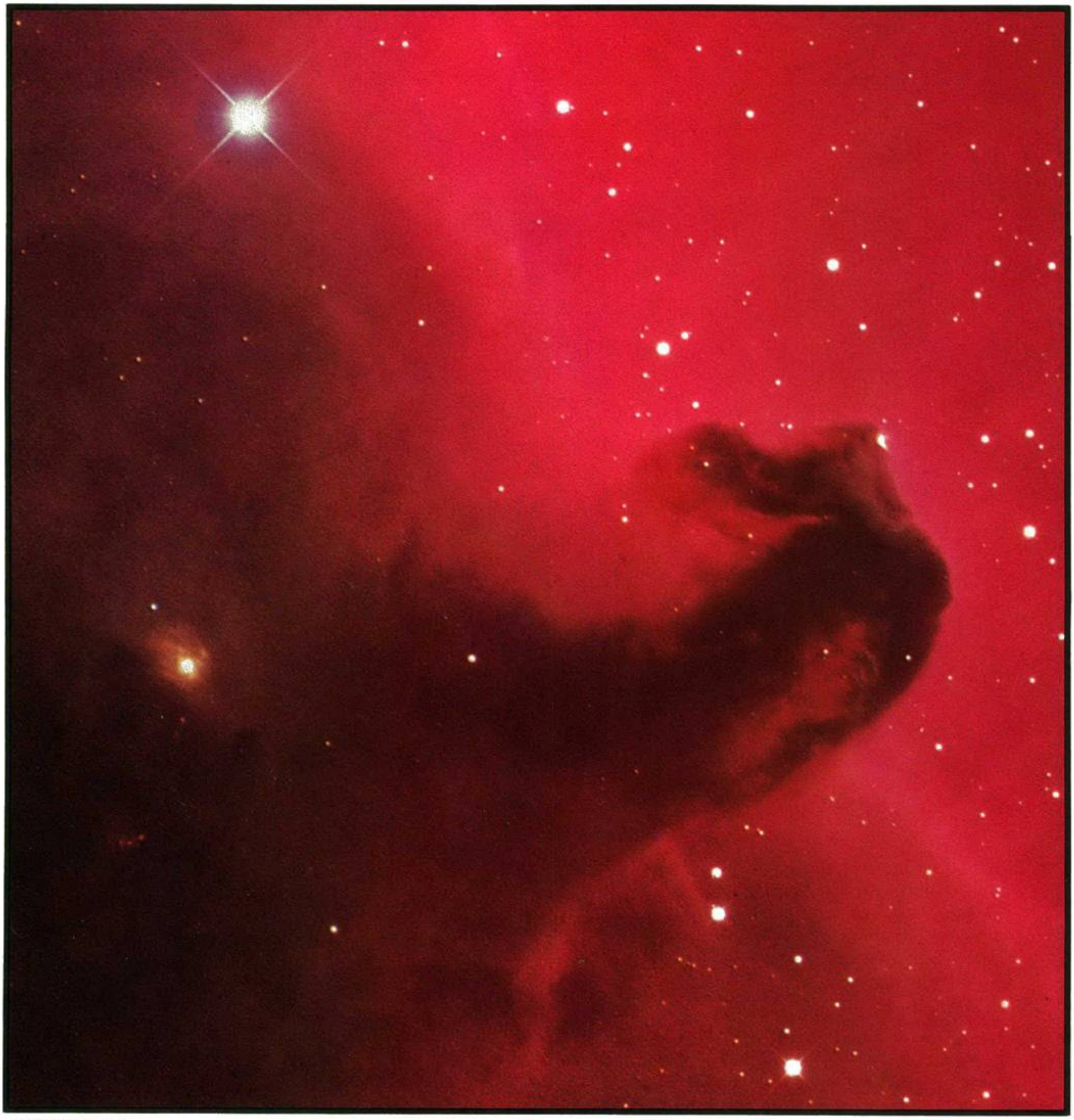

Gas and Dust between the Stars

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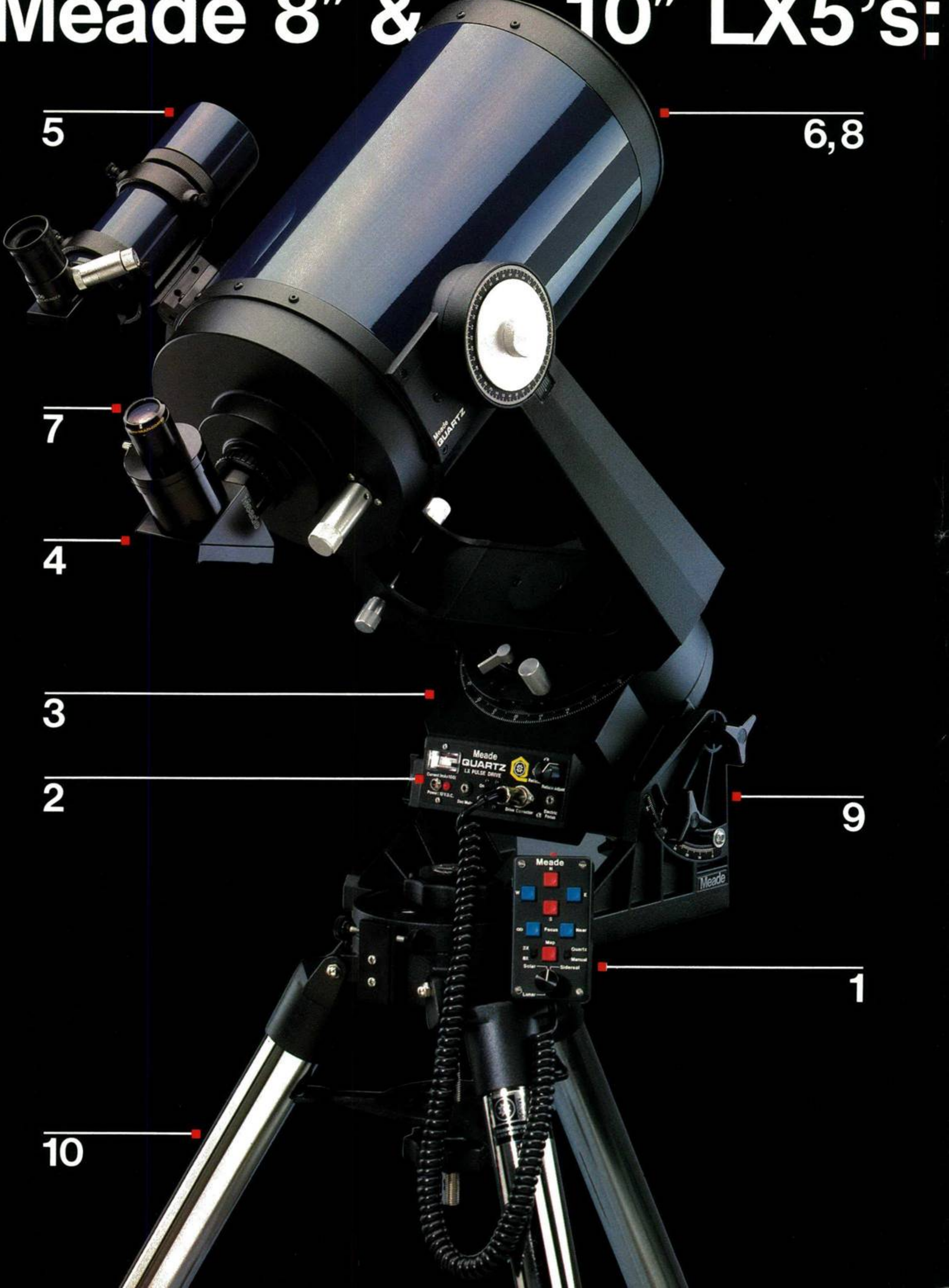
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Cover: Silhouetted against a glowing gas cloud, the dusty Horsehead Nebula illustrates the stark contrasts of the interstellar medium. Anglo-Australian Observatory photo. These pages: The Big Dipper shines through an aurora above Milngavie, Scotland. Photo by Alastair Simmons.

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The Chaotic

High-energy radiation from hot, young stars excites the neighboring interstellar gas to glowing, while dark clouds of interstellar dust obscure some of this light. Photo of NGC 3576 copyright © 1984 by the Anglo-Australian Telescope Board.

Material between the Stars

Hot, cold, dense, and thin — the gas and dust between the stars is anything but uniform.

by Lys Ann Shore and Steven N. Shore

Imagine a place where temperatures and densities vary by factors of a million, where brightnesses range from black to blazing, and where motions go from calm to supersonic. It is a place where stars are born, and a place that is renewed by their death. This is not an imaginary place — you see it every time you look at the Milky Way. This place is the interstellar medium.

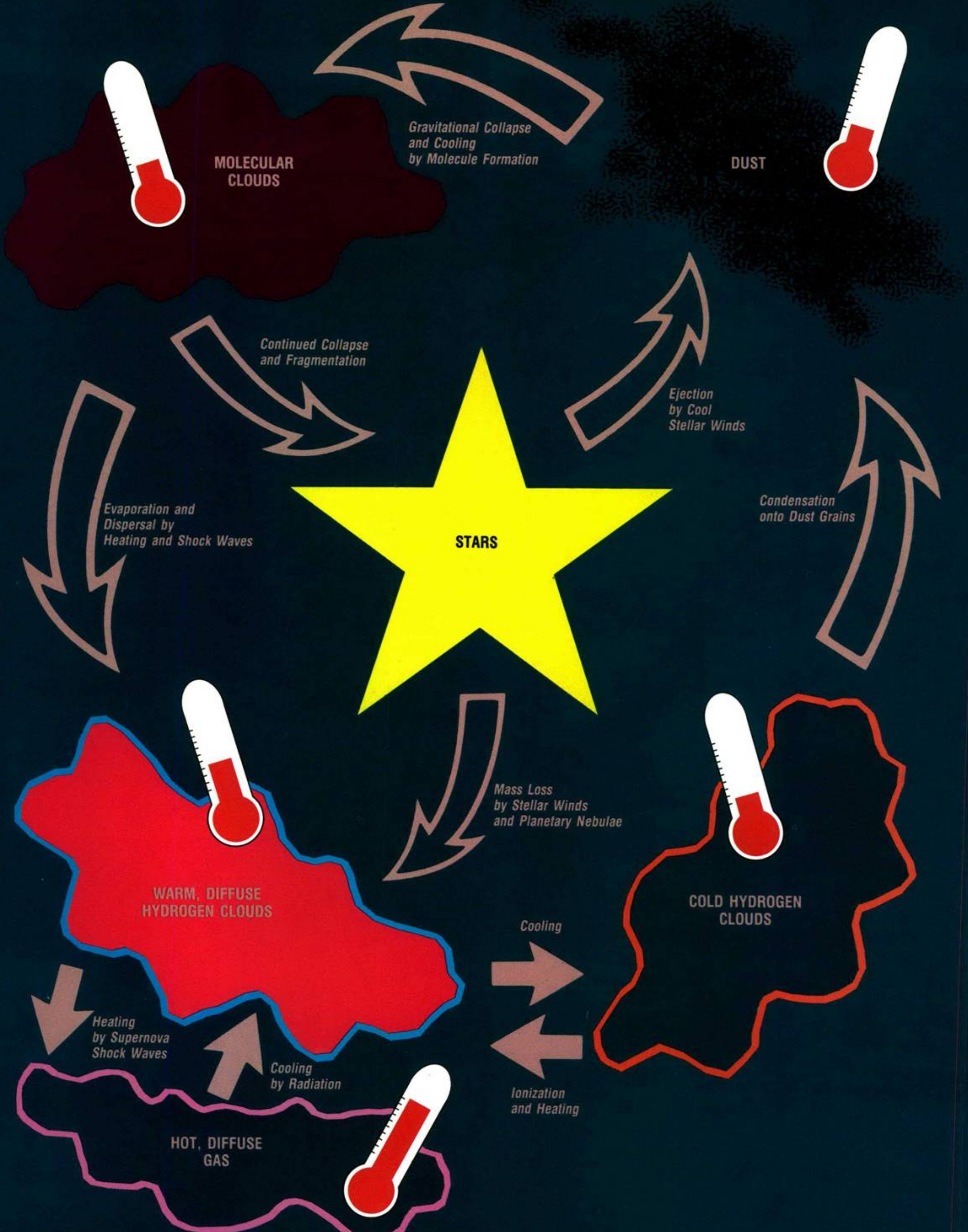
The interstellar medium is made up of all the gas and dust that lies between the stars in the Milky Way Galaxy. This matter gets incorporated into many familiar structures, including supernova remnants, planetary nebulae, emission nebulae, and molecular clouds. But although the interstellar medium permeates our entire Galaxy, it accounts for less than a third of the Galaxy's total mass.

The interstellar medium is far from static. Unlike the quiet place astronomers once envisioned, the interstellar medium is now seen as a dynamic place of startling diversity. "We used to picture the interstellar medium as a bland, low-temperature, uniform environment," said Edward B. Jenkins of Princeton University. "Now we see it as hugely chaotic, with an enormous range of temperatures and an extraordinary contrast of conditions."

Stars and the material between them are so tightly intertwined that astronomers now realize the two cannot be studied apart from one another. Stars form from the gas and dust in the interstellar medium's molecular clouds, and the medium in turn is structured and nurtured by stars as they live and die.

The interstellar medium, which astronomers often call the ISM, is frequently prominent in the immediate vicinity of stars. Clouds of ionized gas up to several hundred light-years across glow from the copious ultraviolet radiation emitted by massive, young stars. The loss of stellar mass causes many of the ISM's other components to be formed. Bubbles are regions of hot gas ejected by "stellar winds" from certain massive stars. Some red giant stars form planetary nebulae at the end of their lives by "puffing off" their outer layers in a low-velocity stellar wind. And most spectacular of all, the titanic explosions of supernovae disperse tens of solar masses of matter into the ISM.

Supernovae also affect the ISM at large distances from stars. The explosions create violent shock waves that travel through the ISM and boost the temperature of the ISM's


MOLECULAR CLOUDS
Gravitational Collapse and Cooling by Molecule Formation
DUST
Continued Collapse and Fragmentation
Ejection by Cool Stellar Winds
Evaporation and Dispersal by Heating and Shock Waves
STARS
Condensation onto Dust Grains
Mass Loss by Stellar Winds and Planetary Nebulae
WARM, DIFFUSE HYDROGEN CLOUDS
COLD HYDROGEN CLOUDS
Cooling
Heating by Supernova Shock Waves
Cooling by Radiation
Ionization and Heating
HOT, DIFFUSE GAS

gas to millions of kelvins. The only parts of the ISM that are not heated by supernova explosions are the denser clouds of neutral hydrogen gas, high-velocity clouds, and molecular clouds.

Inside molecular clouds dust plays an important role in the star-formation process. By shielding the clouds from high-energy radiation, dust permits high-density regions to form. These regions can become so dense that they begin collapsing under their own weight, forming protostars that subsequently develop into stars. Dust also exists throughout the diffuse ISM in wispy patches known as cirrus.

All this dynamic activity takes place in an environment that is far from uniform. The low-density, diffuse part of the interstellar medium is a virtual vacuum — in fact it is a much better vacuum than scientists can achieve in laboratories on Earth — that contains about one atom for every ten cubic centimeters. In this low-density environment an individual atom may collide with another atom only once every 10,000 years, but in the midst of the low-density material are massive molecular clouds 100 million times denser than the diffuse medium.

Over the past forty years a series of major discoveries have profoundly altered our first impressions of the ISM. This change in perspective is largely due to observations of the ISM at a wide range of wavelengths. No longer limited to the optical radiation that penetrates Earth's atmosphere, astronomers can now probe the radio, x-ray, ultraviolet, and infrared emissions of the ISM.

Optical: The Discovery of the ISM

Our understanding of the ISM has changed dramatically since the seventeenth century. Before the invention of the telescope, astronomy was exclusively the study of stars and planets. But with telescopes, astronomers discovered that material existed between the stars.

Gaseous emission nebulae were the first components of the ISM to be discovered. Emission nebulae are regions of gas that have been ionized by high-energy ultraviolet radiation emitted by the hot, young stars embedded in these regions. The gas glows at visible wavelengths as it radiates the energy away.

It was not until early this century, however, that gas was found in the space far from stars and not just surrounding some stars. With the development of spectroscopy, astronomers could analyze light coming from a celestial source and learn about the composition, motion, and temperature of the source.

The new form of interstellar gas first appeared as an anomaly in the optical spectra of some stars. These spectra showed dark absorption lines, caused by ionized calcium and neutral sodium, that arose in gas moving at a velocity different from the velocities of the stars.

This effect was most dramatic in the spectra of binary stars, where the absorption lines of the two stars shifted as a result of the stars' changing orbital velocities, while the absorption lines of the calcium and sodium remained fixed. For this reason the lines were called stationary lines. Characteristic of warm, diffuse gas at temperatures of a few hundred to a few thousand kelvins, the stationary lines tell astronomers about the chemical abundances in gas far from stars, about the density of the gas, and about the dynamics of the gas.

Although most of the mass of interstellar gas is found in dense or diffuse clouds, most of the volume consists of warm or hot diffuse gas. The diffuse gas moves chaotically, as indicated by the stationary lines, which are wider than the thermal motion of the gas would lead us to expect. Michael A. Jura of the University of California at Los Angeles compared the situation to a pot of boiling water. "A lot of dynamic processing, pushing and pulling, is going on, and this keeps the medium turbulent," he said.

The first evidence that dust existed in the interstellar medium came to light in the 1920s and 1930s when interstellar reddening was discovered. Dust grains preferentially absorb and scatter blue light, which causes celestial objects to appear redder than they normally would. For example, a hot star, which emits mostly blue light, might appear redder than a cooler star, or a globular cluster might look redder and fainter than it should, based on its distance.

Though many astronomers like to think of dust grains as spheres, the grains come in a variety of shapes. The first indication that dust grains take many forms came in 1949, when J. S. Hall and W. A. Hiltner discovered the polarization of starlight. Starlight becomes polarized — the direction in which the electromagnetic waves vibrate is not completely random — when the light passes through the dust grains. However, only nonspherical grains can polarize light, and only when the grains are aligned like iron filings in the presence of a magnet. Dust grains may also be shaped like needles or plates, and they're aligned by the weak magnetic field of the Galaxy.

Dust grains come in a broad range of sizes, but most are less than one micron across. The sizes of the grains are inferred from the polarization of starlight: the wavelengths at which maximum polarization occurs roughly correspond to the sizes of the grains that do the polarizing. Because polarization reaches a maximum at optical and near-infrared wavelengths, only relatively large dust particles — about the same size as the wavelength of optical light — need be aligned.

However, astronomers now recognize that starlight is still absorbed and scattered at shorter than visual wavelengths. "This means that some particles are very small," said John S. Mathis of the University of Wisconsin. Astronomers currently believe that the smallest dust grains may be only 20 angstroms across, where 1 angstrom is equal

Stars That Blow 'Bubbles' **Strong stellar winds from some massive stars carry matter outward into the interstellar medium. This matter can form an expanding bubble of hot, ionized gas that glows at a wide range of wavelengths. Photo of NGC 2359 copyright © 1979 by the Anglo-Australian Telescope Board.**

to 1/10,000th micron.

To investigate the question of smaller grains, University of Wisconsin researchers have built an instrument called the Wisconsin Ultraviolet Photopolarimetry Experiment. This instrument will probe for smaller particles in the ISM by observing polarization at ultraviolet wavelengths. The instrument is scheduled to be carried as part of the ASTRO experiment aboard the space shuttle.

With interest increasing in the smaller dust grains, a problem of terminology arises: How small can a grain be before it ought to be called a molecule? Laboratory studies would place the demarcation point between about fifty and a hundred atoms. Above this point the atoms interact with one another so often that they behave collectively, like a solid; at lower numbers the atoms can vibrate individually, like loose beads on a string.

The Makeup of the ISM

What is the interstellar medium made of? The ISM, like the rest of the universe, consists almost entirely of hydrogen. To learn about the abundances of heavier elements in the interstellar gas, astronomers study the absorption lines present in both optical and ultraviolet spectra.

Although differences in composition exist among the various structures in the ISM, the abundances of elements in emission nebulae offer a reasonable approximation of the overall average. Also called H II regions because they consist primarily of ionized hydrogen, emission nebulae are nearly 90 percent hydrogen. For every 10,000 hydrogen atoms, there are approximately 1,200 atoms of helium, 1 or 2 carbon atoms, 1 or 2 nitrogen atoms, 3 or 4 oxygen atoms, 1 neon atom, 1 sulfur atom, and smaller amounts of some heavier elements, particularly iron.

The composition of interstellar dust is much more difficult to determine. The larger grains appear to be made of carbon, silicates, or iron, with ice covering the surface when these grains occur in dense molecular clouds. The smallest grains probably consist of organic molecules much like the large and stable polycyclic aromatic hydrocarbons known from laboratory research.

The existence of these molecules in interstellar space was first hypothesized as a way to explain a series of broad, diffuse interstellar spectral lines. These lines, first observed in the 1930s, are seen in absorption at optical wavelengths and in emission in the infrared. Astronomers do not universally agree on what causes these lines, however. Although laboratory polycyclic aromatic hydrocarbons have spectra similar to what we observe in interstellar space and could withstand the harsh environment, Mathis pointed out that in the laboratory they're seen to have strong absorption bands in the ultraviolet that aren't seen at all in the spectra of interstellar particles. One explanation of this apparent discrepancy is that there are so many different kinds of polycyclic aromatic hydrocarbons in interstellar space that there aren't enough of any one kind to give rise to a characteristic feature.

Heavy elements exist both in interstellar gas and in dust grains, and the elemental abundances in each component of the ISM depend on chemical evolution in the medium. As Jura explained, "Once dust grains are ejected into the ISM, a lot of processing goes on. Material sticks to the grains, and some comes off." The larger dust grains originate as particles of carbon and silicate, which gradually accumulate elements, one atom at a time, through random collisions. Probably 90 percent of the total interstellar abundance of those elements that are not affected by high temperatures, such as calcium, iron, silicon, and titanium, is contained in dust grains. This is because when one of these atoms hits the surface of a grain, it sticks. On the other hand, those elements that evaporate easily, such as carbon, nitrogen, and oxygen, are less likely to stick to a grain because of their atomic structure. For these elements, the amount present in dust is more like one half or two thirds of their total interstellar abundance.

Radio: Clouds of Hydrogen

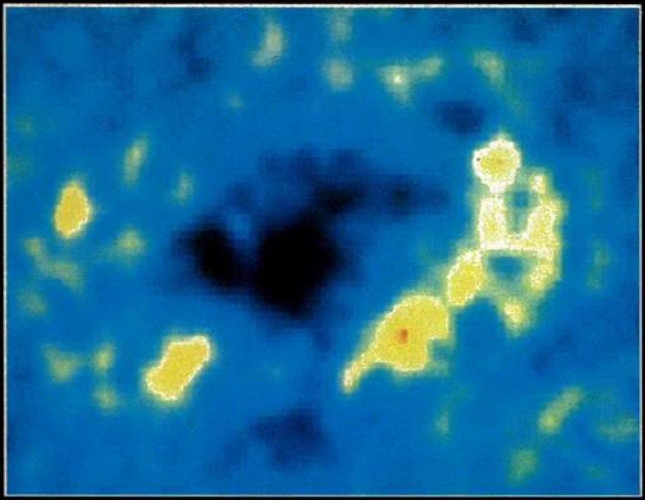
The scientific investigation of the interstellar medium began with optical astronomy. But gas and dust absorb, redden, and can even totally block visible light coming from more distant parts of the ISM. Radio radiation from the ISM, however, does not suffer this fate and passes virtually unimpeded through clouds of interstellar gas and dust, which makes the radio "window" a vital tool for understanding the ISM.

The most important spectral line in the radio region of the electromagnetic spectrum comes from neutral hydrogen and has a wavelength of 21 centimeters. The 21-centimeter line shows the distribution of neutral hydrogen in the ISM. Diffuse, cool hydrogen gas at temperatures less than about 100 kelvins emits 21-centimeter radiation and absorbs the same radiation when a bright background object such as a supernova remnant lies along the same line of sight.

The temperature and density of the hydrogen gas determine the strength of the 21-centimeter line, and the motion of the gas is revealed by the Doppler shift in the 21-centimeter line. Because clouds of neutral hydrogen gas trace the spiral arms of the Milky Way, astronomers use 21-centimeter radiation to map the spiral structure of our Galaxy, which is obscured by dust in the optical.

The 21-centimeter line is now used to study small-scale as well as large-scale galactic structure. For example, although most of the hydrogen atoms found in molecular clouds are bound into hydrogen molecules, a small fraction of the cloud's hydrogen is in the form of neutral atoms. Astronomers can distinguish the neutral hydrogen in molecular clouds from neutral hydrogen in diffuse interstellar gas with a high-resolution instrument such as the Very Large Array. In molecular clouds located near H II

A Field Guide to the Interstellar Medium



Diffuse Neutral Hydrogen Cloud

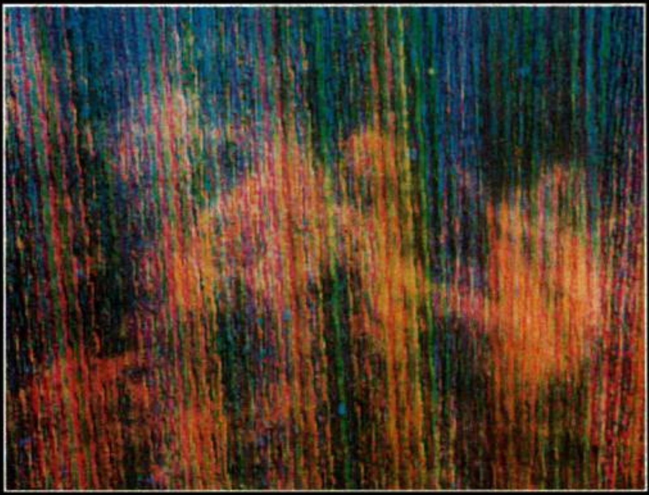
Description: Low-velocity, primarily hydrogen cloud; normal to low metallicity; temperature to a few hundred kelvins; density one to one thousand atoms per cubic centimeter.
Location: Galactic plane.
Life Span: Not well known.
Photo: Neutral hydrogen map of L134 by Miller Goss, NRAO.

H II Region

Description: Ionized region of a gas cloud formed by ultraviolet radiation from hot stars, temperature about 10,000 kelvins but hotter in densest regions, density ranges from less than 1 to more than 1 million atoms per cubic centimeter.
Location: Boundaries of molecular clouds; confined to galactic plane, especially near spiral arms.
Life Span: About 1 million years.
Photo: Lagoon Nebula (M8), U.K. Schmidt Telescope.

Supernova Remnant

Description: Stellar material expelled by explosion into the surrounding space, temperature tens of thousands to millions of kelvins, density tens to thousands of atoms per cubic centimeter.
Location: Wherever massive stars are found, generally within a few hundred light-years of galactic plane.
Life Span: Less than hundreds of thousands of years.
Photo: Crab Nebula (M1), Palomar Mountain Observatory.

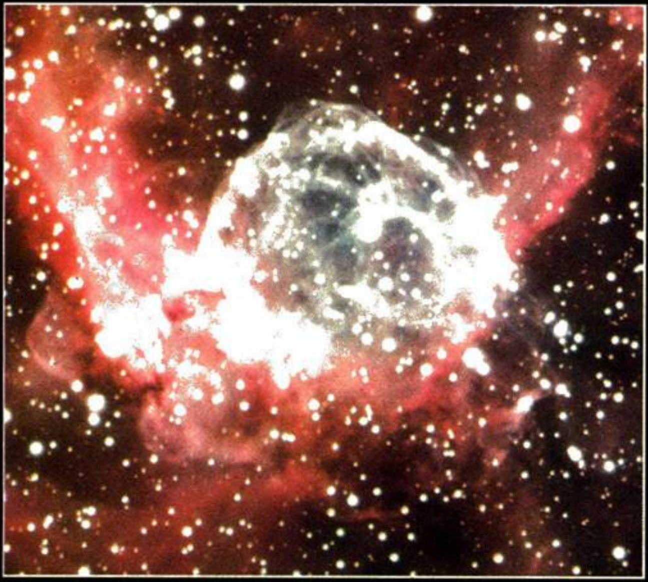


Cirrus

Description: Wispy, diffuse dust; bright in infrared; generally associated with dust in neutral hydrogen clouds; probably caused by small grains or polycyclic aromatic hydrocarbons or something just like them.
Location: In and near galactic plane over most of the Galaxy, appears to avoid the halo.
Life Span: Unknown but probably as long as stars form.
Photo: *IRAS* image of infrared cirrus clouds.

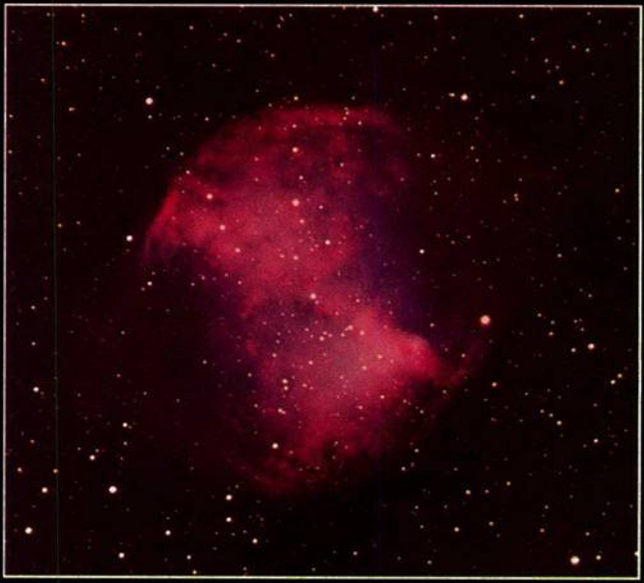
High-Velocity Cloud

Description: High-velocity gas cloud of normal or low metallicity and little or no dust, identified because it moves faster than anything should where it's found, temperature several hundred kelvins, density a few atoms per cubic centimeter.
Location: Anyone's guess but probably in the galactic halo.
Life Span: Unknown.



Bubble

Description: Hot ionized gas formed around massive star by expanding stellar wind, temperature tens of thousands of kelvins, density tens to hundreds of atoms per cubic centimeter.
Location: Immediate neighborhood of massive stars, confined to galactic plane.
Life Span: Tens of thousands of years. (See superbubble.)
Photo: NGC 2359, Anglo-Australian Observatory.



Planetary Nebula

Description: Ionized inner part of low-velocity stellar wind formed by red giant star, temperature about 10,000 kelvins, density tens to thousands of atoms per cubic centimeter.
Location: The entire galaxy but concentrated in galactic bulge and inner halo.
Life Span: Tens to hundreds of thousands of years.
Photo: Dumbbell Nebula (M27), Palomar Mountain Observatory.

Molecular Cloud

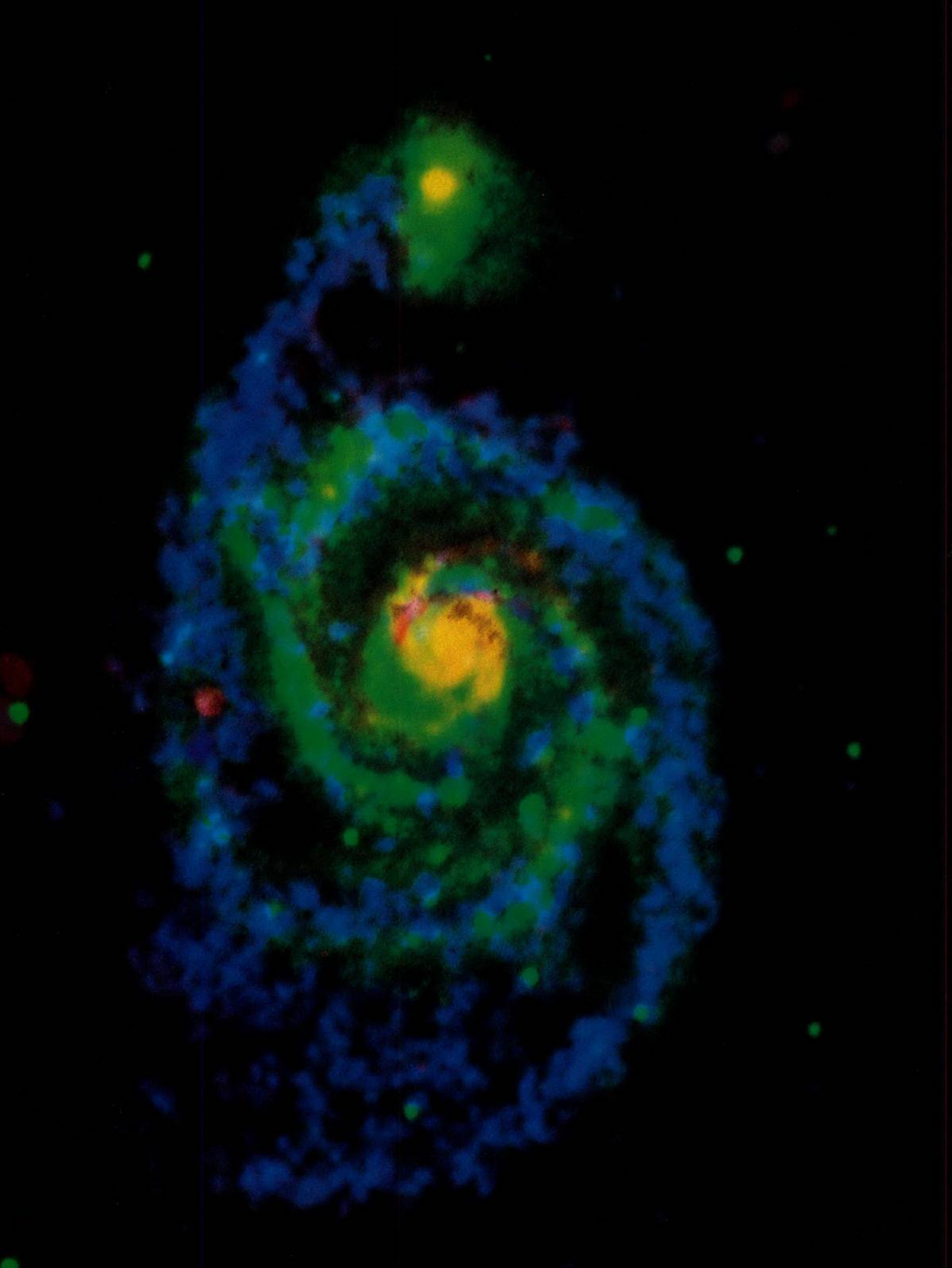
Description: Two varieties: Bok globule (about 1 solar mass) and giant (more than 1 million solar masses), composed of gas and dust, interior temperature tens to hundreds of kelvins, density greater than 10,000 atoms per cubic centimeter.
Location: Less than 200 light-years from galactic plane.
Life Span: About 10 million to 100 million years.
Photo: Barnard 5 molecular cloud, *IRAS* image courtesy Zaqueline Souras.

Protostar

Description: A dense, gravitationally contracting gas cloud on its way to becoming a star; transition phase between molecular cloud and star.
Location: Deep interior of molecular clouds, forms where cloud is most dense.
Life Span: Tens of thousands of years.
Photo: Barnard 5 protostar, *IRAS* image courtesy Zaqueline Souras.

Superbubble

Description: Hot, high-velocity gas around young stellar association; formed by combined effects of stellar winds and supernovae; as energetic as supernova remnants but expanding more slowly; shares most characteristics of bubble, only bigger.
Location: Galactic plane within a few hundred light-years of massive stars.
Life Span: Unknown but probably millions of years.



Stars, Gas, and Dust in the Whirlpool Galaxy **The distribution of stars and the interstellar medium in a spiral galaxy much like our own is shown in this composite image of the Whirlpool Galaxy (M51). Hot, massive stars dominate the visible light image (green), with dust visible as lanes in the galaxy's spiral arms and as an obscuration in the left part of the galaxy's companion at top. Radio continuum emission (red) comes partly from the thermal emission of H II regions and partly from electrons moving in the galaxy's magnetic field. Clouds of neutral hydrogen gas emit 21-centimeter radiation (blue) and trace the galaxy's spiral arms. Image compiled from observations by A. H. Rots, J. M. van der Hulst, P. E. Seiden, R. C. Kennicutt, P. C. Crane, A. Bosma, L. Athanassoula, and D. M. Elmegreen; courtesy NRAO/AUI.**

regions, the neutral hydrogen reveals the interface between the cold molecular cloud and the hot, ionized gas.

One of the most intriguing discoveries made with 21-centimeter observations is clouds of neutral hydrogen moving at speeds much faster than clouds rotating normally in the Galaxy should. Although their existence has been known for some time, these high-velocity clouds are still a subject of controversy. Are they intergalactic gas entering our Galaxy? Are they "fountains" of gas falling back into the Galaxy? Are they far away or relatively nearby? The only thing we know for sure is that they're composed of gas and little or no dust.

Determining the distance of the high-velocity clouds is a central problem, according to Miller Goss of the National Radio Astronomy Observatory. "We know how fast they're moving," Goss said, "but distance estimates vary by factors of ten or a hundred. The first person to measure unambiguously the distance to a high-velocity cloud will have big news." Many astronomers consider the high-velocity clouds to be a tracer of the galactic halo, but because we don't know exactly where they lie, these clouds may not even be in the halo.

Ionized hydrogen in H II regions is the source of a second significant form of radio radiation, radio continuum radiation. H II regions are where interstellar gas and dust overlap: dust is destroyed by ultraviolet radiation and recycled as gas. Radio continuum radiation — so named because the emission occurs not in discrete spectral lines but rather throughout the entire range of radio frequencies — gives astronomers their best look into this dynamic process.

There are actually two kinds of radio continuum emission that come from the ISM: thermal and nonthermal. H II regions generate the thermal emission the same way they generate visible light — by converting ultraviolet radiation from massive stars into lower energy radiation. The strength of the radio emission depends on the temperature and density of the gas.

Astronomers have used thermal emission to make high-resolution radio images of H II regions, but they do not yet have a complete picture of the overlap between interstellar gas and dust. To get that picture, infrared observations are needed in addition to the radio observations. Michal Simon of the State University of New York at Stony Brook pointed out that although the Very Large Array can provide high-resolution images of these regions, nothing comparable was available for infrared work until recently. "Any imaging has been done very painfully, pixel by pixel. This is excruciatingly time-consuming," he said. Now, however, infrared cameras that can produce an image a few arcminutes on a side — a resolution approaching what the Very Large Array can achieve —are becoming available.

The second kind of radio continuum emission, the nonthermal radio emission, was discovered by Karl Jansky in the 1930s; this was the first time radio radiation was detected from space. The nonthermal emission is due to high-energy, cosmic-ray electrons spiraling along the field lines of the Galaxy's magnetic field. The radiation is called nonthermal because its strength does not depend on the electrons' temperature.

Ultraviolet: Seeing It All

Ultraviolet observations of the ISM reveal a wider range of densities, a wider range of temperatures, and a wider variety of ingredients than revealed in any other wavelength region. While only relatively few elements in interstellar gas have spectral lines that are visible at optical wavelengths, ultraviolet spectral lines show the entire range of ingredients.

Before space-based ultraviolet observatories existed, astronomers believed the abundances of elements in the ISM would not be much below the abundances found in the Sun and other stars. But ultraviolet satellites found that the abundances of many elements were much lower than expected. Based on the strengths of ultraviolet spectral lines, astronomers concluded that many elements heavier than helium had abundances as much as a thousand times below expectations.

Surprisingly, not all the elements examined were equally depleted. The differing amounts of depletion turn out to depend on the density of the gas, and the reason for that provides an insight into the dynamic interaction of gas and dust in the ISM.

Element depletion is greater in high-density regions than in low-density regions, because gas is more likely to stick to dust grains in a high-density region and more likely to be liberated from dust grains in a low-density region. Element depletion occurs because atoms in the interstellar gas "freeze" onto dust grains. This happens more frequently in high-density regions because the number of collisions between atoms and dust particles is greater than in low-density regions.

When dust grains are destroyed, however, element abundances in the gas are enhanced. Dust grains can be vaporized when a shock wave, perhaps from a nearby supernova, passes through the ISM; the atoms in the dust grains then get released back into the gas phase. Because shock waves have a greater impact at lower densities, low-density regions tend to be less depleted.

Another unexpected discovery to come out of ultraviolet observations was that very high temperatures — a million kelvins or so — existed in some regions of the interstellar gas. The likeliest cause was supernova explosions. According to Jenkins, "This showed that supernovae had a strong effect at much more than a local level. The strength of the propagation hadn't been understood before." The discovery of high-temperature gas dramat-

A Supernova Replenishes the Interstellar Medium Gas in the expanding shell of a supernova remnant rejoins the interstellar medium. A supernova explosion ends a star's life, but it also enriches the material between stars with up to a few tens of solar masses of matter. In addition, violent shock waves created in supernova explosions heat the diffuse gas in the interstellar medium to over a million kelvins. Photo of the Veil Nebula supernova remnant courtesy National Optical Astronomy Observatories.

ically changed our overall conception of the ISM and contributed to the current view of its complex, chaotic nature.

Astronomers hope that the proposed LYMAN satellite will extend ultraviolet observations even farther within the next decade. The far-ultraviolet region of the electromagnetic spectrum, from 912 angstroms down to about 40 angstroms, is sometimes called the "black pit," because interstellar gas is most opaque at these wavelengths. Far-ultraviolet radiation easily ionizes most atoms, including hydrogen, so it is absorbed very effectively by the gas. With a few exceptions caused by the patchiness of the local ISM, our view at these wavelengths will be limited to about 100 light-years.

LYMAN will observe radiation with wavelengths shorter than 1200 angstroms, which would bring important spectral lines caused by ionized oxygen, molecular hydrogen, and atomic hydrogen into view. In addition, LYMAN would observe spectral lines caused by deuterium — a rare form of hydrogen — and from them determine the abundance of deuterium more accurately than was possible with previous satellites. This is particularly important because deuterium is a direct result of the Big Bang and its abundance is a sensitive indicator of whether the universe will expand forever or one day stop and collapse.

The composition of interstellar dust is another question that ultraviolet observations can help answer. An extremely strong absorption feature appears in ultraviolet spectra at a wavelength of 2200 angstroms. This so-called UV extinction bump can block as much as 70 percent of the light emitted by a star at that wavelength. Most astronomers attribute the bump to the presence of graphite in interstellar dust. As John Mathis explained, "Dust is produced by carbon-rich stars, so almost certainly there's carbon in interstellar space. Graphite is the most ordered form of carbon, and if you look at graphite in the laboratory, you get a good fit with the shape of the 2200-angstrom feature."

The UV extinction bump indicates that dust grains consist of graphite, and infrared observations suggest that many of these grains have hydrogen attached to them. Thus, said Mathis, "most people would say the bump is due to small, slightly disordered bits of graphite, many with hydrogen on the outside." But, as is typical in astronomy, agreement isn't universal: some astronomers argue that the bump could be caused by silicate grains rather than graphite. Whatever the bump's source, however, the strength of the bump isn't uniform throughout the Galaxy, and it also varies from one galaxy to another — an indication that the grain composition, size, and perhaps even source may vary as well.

X-Rays: A Clear View of the Gas

The highest temperature components of the ISM shine brightly at x-ray wavelengths. X-ray observations tell astronomers about hot gas in the ISM — interstellar dust is totally transparent to x-rays — and reveal the startling fact that supernova explosions heat much of the ISM.

Supernova explosions heat the low-density interstellar gas to temperatures greater than a million kelvins. The frequency of supernovae is high enough that the remnants of the explosions overlap, which heats the entire ISM except for cold, dense clouds. "Every point in the ISM is hit by a supernova shock about every million years and so is subject to all the high-energy electrons that keep the heat up," explained Donald G. York of the University of Chicago, "and the time it takes the ISM to cool is much longer than a million years."

Astronomers believe the extremely hot, low-density gas revealed by the x-ray emission is in the galactic halo, because gas at such high temperatures travels fast enough to escape the Galaxy. Ultraviolet observations made with the COPERNICUS satellite confirmed that a "galactic corona" of hot gas exists far from the plane of the Milky Way. And observations of the Magellanic Clouds and quasars at high galactic latitudes by the *International Ultraviolet Explorer* satellite confirmed that some of the absorption lines present in their spectra come from gas in the Galaxy's halo.

X-rays are valuable tools for exploring both the large-scale and small-scale structure of the ISM, down to the level of our solar system. For example, observations of the solar neighborhood show that the Sun sits on the edge of a very large "hole" in the ISM — a hole that could be the result of an old supernova. York described the local ISM as a region of extremely low density, with hot gas filling 99 percent of its volume and ten or twenty cold clouds (not molecular clouds) of a few solar masses in size.

The local region may be an example of a "bubble" in the galactic ISM. Bubbles and their larger cousins "superbubbles" are regions of low-density, hot interstellar gas surrounding massive stars and associations of massive stars. Astronomers believe these structures result from stellar winds and supernovae.

Infrared: The Glowing Coals

Interstellar dust is a major constituent of the ISM, yet astronomers never saw this dust directly before the advent of infrared astronomy. At optical wavelengths the existence of interstellar dust had to be inferred from reddening and the polarization of starlight, but at infrared wavelengths interstellar dust glows brightly as dust particles reradiate energy they absorbed from high-energy radiation.

It was not until the launch of the *Infrared Astronomical Satellite (IRAS)* five years ago that astronomers got their first clear view of the infrared universe. The satellite surveyed the entire sky at four infrared wavelengths — 12, 25, 60, and 100 microns — selected because Earth's atmosphere is either largely or completely opaque to this

The Birthplace of Stars **Gas and dust in the interstellar medium form stars inside cool molecular clouds. One such region of active star formation is the Orion Molecular Cloud, which dominates the lower half of this false-color image from the *Infrared Astronomical Satellite*. Visible in the image's center, the expanding gas around a hot, young star sweeps up a shell of gas as it expands. *IRAS* photo courtesy Zaqueline Souras.**

wavelength radiation.

Before *IRAS*, diffuse dust was known to exist between interstellar clouds, but the satellite provided astronomers with their first direct view of the dust. Dubbed "cirrus" because its wispy, patchy appearance resembles that of cirrus clouds, this diffuse dust produces the largest fraction of the Galaxy's infrared radiation. *IRAS* showed that the cirrus has a filamentary structure at scales as small as a few arcminutes and as large as a few degrees.

The size and composition of dust particles in the cirrus are still open questions. *IRAS* data indicate that the particles are probably quite small, possibly as small as 20 angstroms across. The composition of the particles remains a controversial issue among astronomers, though graphite, silicate, and polycyclic aromatic hydrocarbons are all good candidates.

Michael G. Hauser of NASA-Goddard Space Flight Center, project scientist for *IRAS*, noted that *IRAS* revealed one "totally unexpected property" of the cirrus: "it was not just radiating strongly at 100 microns, it was also quite bright at the shorter wavelengths. That was astonishing because if this had been ordinary dust, it would have been at 20 or 30 degrees and radiating at 60 or 100 microns but not at all at 12 or 25 microns. This told us there was some other process going on."

One likely possibility is that the cirrus contains a population of grains smaller than astronomers had presumed. Smaller grains heat up faster when they are bombarded by radiation and they would reradiate this energy at wavelengths shorter than 60 microns as they cool. This finding may connect the diffuse interstellar absorption lines seen optically with the cirrus and the small dust particles. If the absorption lines are caused by polycyclic aromatic hydrocarbons, then these large molecules may also be the small grains revealed in the *IRAS* data.

Astronomers also got an unprecedented view of the star-formation process with *IRAS*. Because dark molecular clouds are more transparent at infrared wavelengths than they are at optical wavelengths, *IRAS* was able to look directly into the interiors of these clouds where stars presumably form. Prevailing theory says that stars form when a large enough mass exists in a region cool enough for the material to collapse under its own weight. When a cloud forms it shields its own interior from radiation, which allows molecules to form. Once molecules form, the cloud cools very efficiently because, unlike atoms, molecules can rotate and vibrate when they are hit by another particle. The molecules emit low-energy radiation after these collisions. Because the cloud is transparent to most of this radiation, the energy can escape and the cloud can cool. Also, because molecules and dust absorb ultraviolet radiation efficiently, they shield the interior of the cloud from heating by background radiation. As the cloud cools its internal pressure drops, which causes a collapse that leads to star formation.

IRAS showed that molecular clouds are full of star-forming activity. The satellite detected massive stars in molecular clouds throughout a large part of the Galaxy and comparatively low-mass stars in nearby molecular clouds in Taurus and Ophiuchus. "But there's a fair leap from detecting an object to being able to describe what its evolutionary status might be," Hauser noted. Nonetheless, it's likely that *IRAS* uncovered protostars — stars still accreting mass and that have not yet begun nuclear burning — the transition phase between ISM and star.

Millimeter: The Chemical Factory Revealed

Dark clouds are chemical factories that process interstellar gas into complex molecules and these molecules emit radiation primarily in the millimeter and submillimeter wavelength range. Because molecular emission is very sensitive to temperature and density, it is the most precise probe of the small-scale structure and dynamics of the interiors of molecular clouds. Because the emission occurs in discrete spectral lines, the motions of the gas can be observed directly, even in the densest parts of the cloud, which are opaque to all other radiation.

Current research is concentrated in two areas: astrochemistry, which tries to look at the different constituent molecules involved in chemical reactions in the clouds; and high-resolution maps of the dynamics of specific molecules. The combination of these two investigative lines provides the link between the stage when the clouds form and the conditions that precede star formation. Perhaps the most important result to come from these studies is the discovery in many molecular clouds of very small turbulent regions, less than one tenth of a parsec in size — a scale small enough to herald the birth of stars.

At every wavelength the interstellar medium appears to be a complex, changing environment, far different from the cold, dead place astronomers originally thought it was. The interactions of atoms, molecules, and dust grains in the ISM take place in time as well as space. The ISM feels the effects of a violent event, such as a supernova explosion, for a very long time, as the heated gas gradually cools and partially condenses onto dust grains, which in turn form clouds, which eventually form stars. That these processes take a long time to happen isn't really important in a place where the life of a dust grain is typically millions of years. In this amazing environment, said H. C. van de Hulst, a pioneer of ISM research, "each atom can think for a million years and still act spontaneously."

Lys Ann Shore is a writer and editor who writes frequently about astronomy and lives in Socorro, New Mexico. She wrote "The Telescope That Never Sleeps," which appeared in the August 1987 issue. Steven N. Shore is a member of the Astrophysics Research Center and Langmuir Laboratory and associate professor of physics at New Mexico Institute of Mining and Technology in Socorro.

Quest for the Most Distant Objects in the Universe

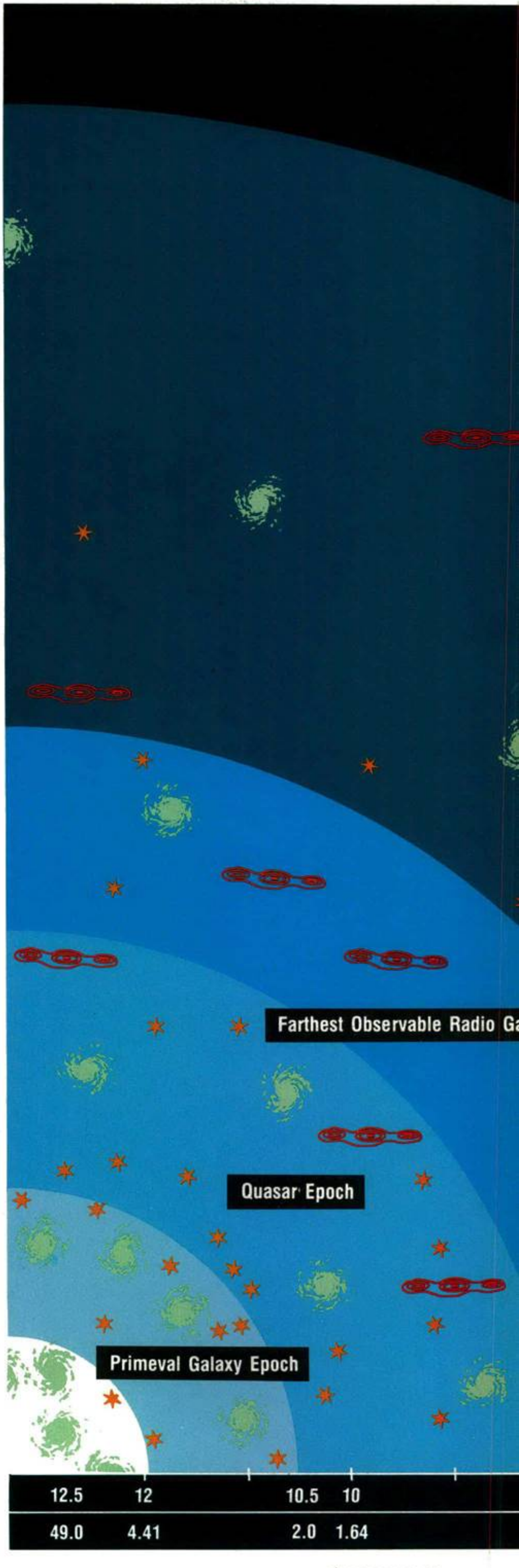
Recent discoveries of distant quasars and galaxies threaten to topple our best theories of galaxy formation.

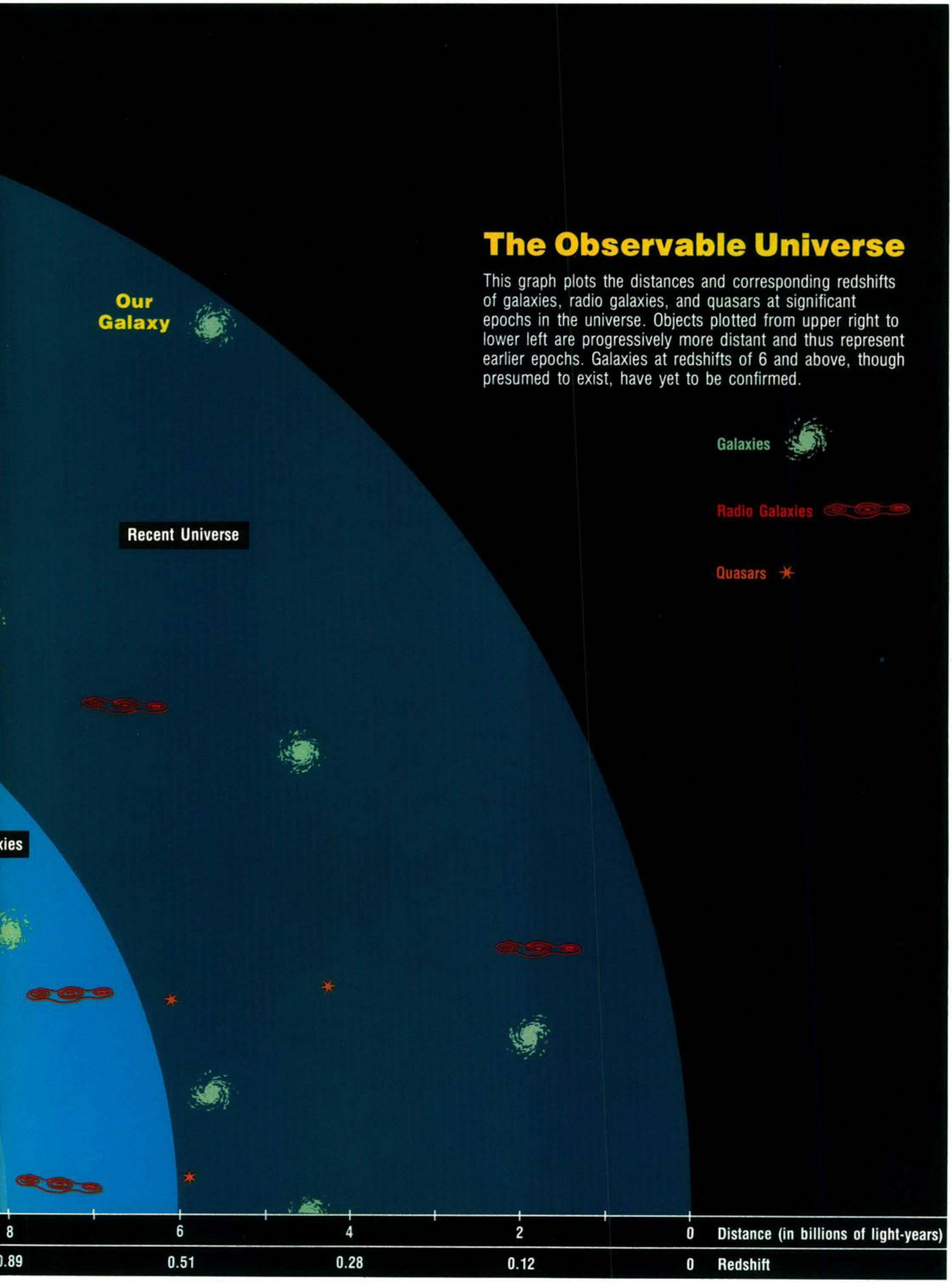
by Jeff Kanipe

Far out in the distant universe, between 10 billion and 11 billion years away in space and time, lies a region where the majority of known quasars resides. Astronomers have known about this stratum of quasars for over two decades and have spent the better part of that time trying to understand why these objects seem predisposed to congregate at this distance. The most plausible explanation is that there were more quasars 10 billion or 11 billion years ago than there are now and that this region represents, in effect, the quasar "spawning grounds."

For astronomers this quasar stratum has played an important role in demarcating the edge of the observable universe. Beyond lies only a handful of more distant quasars, and beyond that lies a vast, impenetrable region that extends back to a time before the quasars formed, when matter and photons went their separate ways 700,000 years after the Big Bang. Galaxies and quasars won't be found in this wasteland, according to one of the best theories of galaxy formation, because these objects don't exist here: in other words, at that stage in the history of the universe galaxies had yet to congeal from primordial gas clouds.

But a recent flurry of back-to-back quasar discoveries may spell the beginning of the end of this theory. Between August 1986 and late September 1987 more than a half-dozen quasars were detected at 12 billion light-years, which is beyond what astronomers had considered the edge of the universe. Although the new quasars may not seem to be too far out of bounds, a little distance translates into a lot of time in the development of the young universe, just as a few months make quite a bit of difference in the development of an infant.



# The Observable Universe

This graph plots the distances and corresponding redshifts of galaxies, radio galaxies, and quasars at significant epochs in the universe. Objects plotted from upper right to lower left are progressively more distant and thus represent earlier epochs. Galaxies at redshifts of 6 and above, though presumed to exist, have yet to be confirmed.

Our Galaxy
Recent Universe
ies
Galaxies
Radio Galaxies
Quasars
8
6
4
2
0
Distance (in billions of light-years)
.89
0.51
0.28
0.12
0
Redshift

The final stroke would be the discovery of quasars or possibly primeval galaxies in a region of space thought to predate the formation of galaxies. Theorists would then be forced to discard established models that explain how galaxies formed and evolved and to devise new theories that better reflect observations. This would cause a major revolution in astronomy.

The End of a Beautiful Relationship

But revolutions are nothing new in astronomy. Not too long ago in the late 1950s and early 1960s the universe seemed to be a cozy little place where events reflected theory to the point of predictability. Though the expansion of the universe was not well understood, astronomers didn't find anything particularly odd about the galaxies partaking in that expansion. Even the stars within those galaxies appeared to dutifully follow the laws of physics.

The only exceptions were some curious stars discovered between 1960 and 1962 that emitted great amounts of radio energy and displayed strange, enigmatic spectra. Astronomers believed these quasars, as they came to be called, were simply a new type of oddball star: they didn't consider quasars a threat to ideas held sacred about the universe.

Things began to unravel in 1963 when the quasars' spectra were finally deciphered and showed that quasars lie at great distances and recede at incredible velocities. Though the quasars weren't as distant as the most distant galaxies (estimated at 6.5 billion light-years away) quasars were nevertheless a thorn in the side of theorists who had to explain how such distant objects could be so luminous.

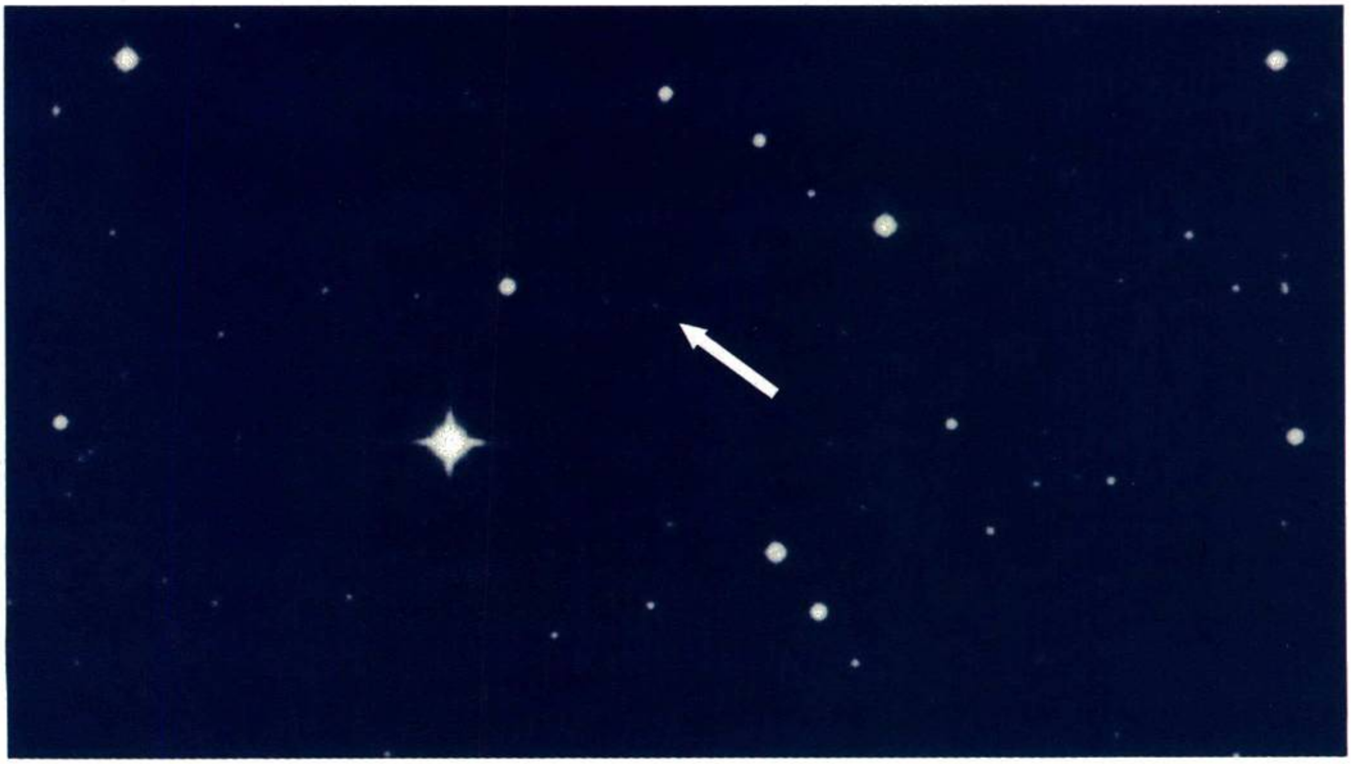
But the big shock came in 1965 when astronomer Maarten Schmidt of the California Institute of Technology announced the discovery of a quasar, 3C 9, that lay 10.5 billion light-years away and receded at 240,000 kilometers a second — 80 percent the velocity of light! In one stroke this quasar not only nearly doubled the size of the universe, but when light-travel time was considered, it also nearly doubled the universe's age. Suddenly the idyllic existence of astronomers was thrown into turmoil; many formerly "inviolable" beliefs astronomers had held about galaxy formation and the early universe were found wanting.

Although this discovery plainly marked the end of a beautiful relationship between observation and theory, it also marked the beginning of an intense search for objects that were even more distant — and for theories to explain the existence of these objects.

Over the next decade quasars were found at greater and greater distances; the culminating discovery was OQ172 in 1973, an object that lay over 11.5 billion light-years away. For almost ten years this quasar was listed in the *International Guinness Book of World Records* as the most distant object in the universe. Between 1973 and 1982, 1,500 new quasar discoveries were racked up. Only one quasar — PKS 2000 −330 — was more distant than OQ172 (by about 200 million light-years). That PKS 2000 −330 wasn't much more distant than OQ172 didn't matter to the theorists. The distance barrier had been broken once again and many were wondering if this would be the last time.

In fact, the barrier would be broken several more times, all within the course of a year. As of this writing, the most distant object in the universe is Q0051 −279, a quasar discovered in September 1987 by Stephen Warren, Paul Hewett, and Michael Irwin of Cambridge University's Institute of Astronomy. The quasar's distance

The Most Distant Object . . . So Far This tiny speck is the quasar Q0051 −279. With a redshift of 4.43, it is the most distant known object in the universe today. The light from this quasar began its journey Earthward 12 billion years ago, when the universe was young. Photo courtesy of the Royal Observatory, Edinburgh.



is calculated at 12 billion light-years. Just a few weeks after this discovery Mark Dickinson and Patrick McCarthy — doctoral candidates at the University of California at Berkeley — happened on the second-most distant quasar while looking at an unusual radio galaxy. Designated Q2203 +292, this quasar's distance is just under 12 billion light-years.

Seeking Higher Redshifts

By the time the light from the recently discovered quasars reaches Earth, the light's wavelengths have been stretched or made longer by well over 400 percent because the universe is expanding. This wavelength stretching causes the object's spectral lines to shift dramatically toward the red end of the spectrum. Astronomers call this phenomenon a redshift, and it is a telling factor in differentiating quasars from stars and nearby galaxies.

The redshift of an object represents the amount the universe has expanded since the time the object's light was emitted. Astronomers denote this value by the symbol z. The z value can be converted from the percentage of spectral line displacement by simply dividing the percentage by 100. Thus, an object with a 200 percent shift in spectral lines (e.g., the quasar 3C 9) has a z of 2; a 180 percent shift represents a z value of 1.8. The two most distant quasars known have z values of 4.40 and 4.43.

When astronomers refer to an object's redshift, they mean the object's *expansion* redshift value. The term conveniently encompasses how far away an object is, how long ago it emitted its light, and how much the universe has expanded since then. Objects with higher z values lie at greater distances and consequently represent earlier epochs in the universe. Thus, the goal of looking for objects at greater and greater redshifts, other than the sport of the search itself, is to look back to the epoch of galaxy formation.

> ***"We're seeing these objects at distances far beyond where people ever hoped to see galaxies ten to fifteen years ago. We're seeing these things as they were in their early stages."***
>
> ***— Pat Osmer***

Andrew Fraknoi

"The great interest of studying quasars at high redshifts," said Pat Osmer, a quasar astronomer at Kitt Peak National Observatory, "is that these are the most distant, identifiable, discrete objects we can see in space. We're seeing these objects at distances far beyond where people ever hoped to see galaxies ten to fifteen years ago. The light-travel time for a redshift of 2 or 3 is such a big fraction of the age of the universe that we're seeing these things as they were in their early stages."

Finding High-Redshift Quasars

Osmer, who verified a 4.07-redshift quasar last August with the 4-meter reflector at Cerro Tololo, believes a "redshift barrier" — beyond which there are no quasars — could tell astronomers which epoch the quasars formed in. There is no question that existing telescopes are powerful enough to search for this epoch of formation, Osmer added. "The power of our telescopes is more than adequate to see quasars at higher redshifts."

The real problem for astronomers has been identifying high-redshift quasars. Previous optical techniques were better suited to finding quasars with redshifts less than 2. The redshifts of these quasars are great enough to shift visible light into the infrared and ultraviolet light into visible wavelengths. This "ultraviolet excess" makes quasars look very blue and thus makes them easy for the human eye to spot on photographic plates. At higher redshifts, however, these colors are shifted toward even longer wavelengths, so the quasar is reddened and more difficult for the eye to see.

Fortunately, new optical techniques have greatly facilitated the search for high-redshift quasars. One successful but rather elaborate method capitalizes on the distinctly nonstellar color profiles of the emission and absorption features high-redshift quasars have. These characteristics can be searched for on photographic plates and yield a list of quasar candidates that can later be investigated more closely.

The method utilizes a laser-scanning device that was developed at Cambridge University and successfully used at the Anglo-Australian Observatory in Australia. Called the automatic plate-measuring facility (APM) — or more informally the "Kibblewhite machine" after its inventor, Ed Kibblewhite of Kitt Peak National Observatory — the instrument takes only a day to read the positions and magnitudes of 200,000 stars and galaxies on a plate covering 30 square degrees of sky.

First, photos are taken of the same area of sky with different filters — ultraviolet, blue, visual, red, and infrared. The APM then compares two plates in each of the five colors and essentially sorts stars from nonstars. The nonstars make up the list of potential quasar candidates. Astronomers go back and make spectroscopic observations of the candidates to weed out the objects that aren't quasars.

Last year the APM was put to work culling the stars on new plates of the sky surrounding the south galactic pole taken by the UK Schmidt Telescope. This region, located in the southern constellation Sculptor, is clear of the obscuring band of dust and gas in the Milky Way and thus astronomers can look deeply into extragalactic space.

Of the eighty best candidates identified on the plates by the APM, twenty-four were quasars with redshifts greater than 3 — seventeen of those were previously unknown. Of the seventeen new quasars, two had redshifts greater than 4: the 4.07-redshift quasar discovered

'How Far' Depends on the Universe You Choose

The expansion of the universe provides astronomers with a convenient method for finding the distances to galaxies and quasars. But to convert the measured recession velocity of any object to a distance, astronomers must assume *the rate* at which the universe is expanding.

The expansion rate, called the Hubble constant and symbolized by H_0, has been measured at between 50 and 100 kilometers per second per megaparsec. Thus, a galaxy receding at 6,000 kilometers per second is 200 million to 400 million light-years (60 to 120 megaparsecs) away.

However, when we look at galaxies and quasars at great distances — more than a billion light-years — we are looking back to a time when the expansion rate may have been greater. This change in the rate of universal expansion, caused by gravity's influence on matter, is expressed by the deceleration parameter, symbolized by q_0. Most astronomers believe q_0 equals 0 or 1/2.

A universe in which $q_0 = 0$ is said to be "open" and will expand forever at a constant rate. A universe in which $q_0 = 1/2$ is said to be "flat" and will expand forever but at an ever-decreasing rate. And a universe in which q_0 is greater than 1/2 is said to be "closed," which means gravity will eventually overcome universal expansion and cause the universe to collapse again. Most of the present day evidence favors an open or a flat universe; a closed universe requires more matter than is currently observed.

To some extent an astronomer's choice of values for the Hubble constant and deceleration parameter is based on the kind of universe he favors: open, flat, or closed. Naturally, each universe uses a different set of values, and each set of values, in turn, yields different distances for the same object.

For example, with $H_0 = 50$ and $q_0 = 0$, the distance to a redshift 4 quasar is 15.5 billion light-years; with $H_0 = 100$ and $q_0 = 1/2$, the distance "shrinks" to about 6 billion light-years!

For this article, all distances assume a Hubble constant of 50 and a deceleration parameter of 1/2. These values were chosen — not because they are incontestable — but because they were preferred by a majority of the astronomers interviewed.

by Osmer and the 4.43-redshift quasar discovered by Warren, Hewett, and Irwin.

"In this business," Osmer said in reference to the number of quasars identified on the plate, "that's a good sized sample. In fact, at first sight it looks like a surprisingly large figure, but this is a huge area covered to a very faint limit."

A Serendipitous Discovery

The APM has not only streamlined a very methodical and tedious search process, it has also produced results in areas of the sky where two previous searches found nothing with a redshift much above 3. (Osmer conducted one search while at Cerro Tololo; the other was conducted by Maarten Schmidt and his collaborators at Palomar Observatory.) But while these systematic efforts have paid off handsomely in the discovery of the most distant objects in the universe, so has good old-fashioned luck.

On the night of September 25, 1987, Patrick McCarthy and Mark Dickinson began an observing run on the 3-meter telescope at Lick Observatory on Mount Hamilton. Their mission was to obtain spectra of 3C 441, a high-redshift (0.7) radio galaxy, and its companion galaxy, which sits along a jet emitted by the radio galaxy. (A radio galaxy is a member of the class of active galaxies that emits great amounts of radio energy.) With the spectra they hoped to learn about the properties of the environment surrounding this energetic galaxy.

To get both spectra simultaneously, the astronomers attached a long-slit spectrograph to the telescope. The slit allows a "slice" of the object's light to pass through the spectrograph. This slit is 2 arcminutes long and 2 arcseconds wide, which amounts to only 1/54,000th of a square degree of sky. A charge-coupled device (CCD) was used to record the spectra.

McCarthy and Dickinson oriented the spectrograph's slit over both the radio galaxy and the companion and began the exposure. An hour later they looked at the CCD read-out and saw the galaxy and the companion clearly enough. But there was also a strange-looking object in the slit.

"We were quite surprised to see another object falling some distance away but along the slit that had a spectrum that immediately shouted out to us 'quasar,'" recalled Mark Dickinson. "It was a point source. We lay another slit down and confirmed that the object was a quasar. Then we did a little arithmetic and came up with a redshift of 4.40.

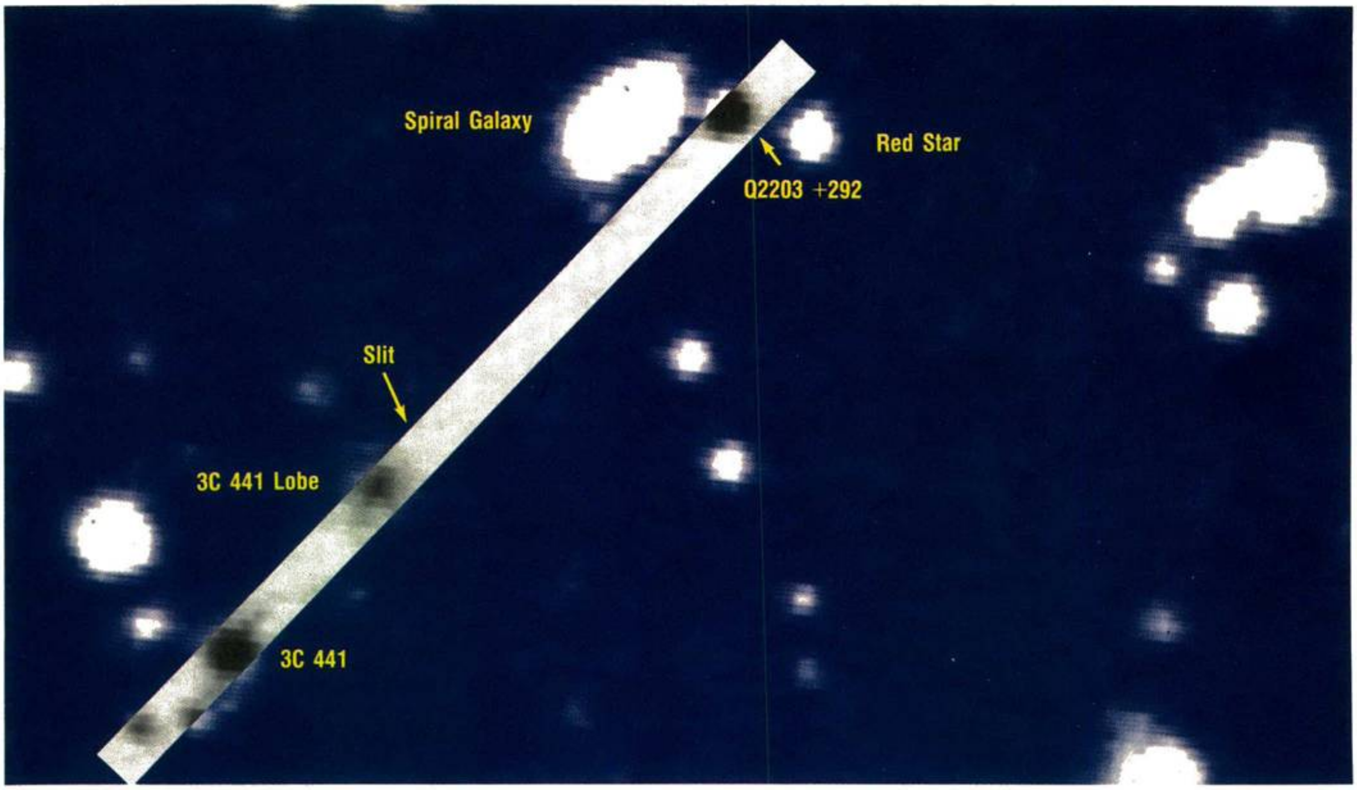
"In the time we've been looking, you might find one quasar of some redshift in 1/100th of a square degree. But the fact that it has a redshift of 4.4 is baffling."

The Redshift Cutoff

A high-redshift quasar was discovered almost randomly. Three weeks before McCarthy and Dickinson's discovery, Warren, Hewett, and Irwin had discovered their redshift 4.43 quasar on a plate covering 30 square degrees after systematically laser-scanning the images and following up with spectroscopic observations. McCarthy and Dickinson observed a fraction of an area of sky and, without trying, picked up the second-most distant quasar known. Some astronomers wonder if this serendipitous discovery means there are more quasars at greater redshifts than previously believed. Had earlier surveys missed these objects, or was there some other reason high-redshift quasars might have been missed?

"The density of these quasars in the sky isn't known at all," said McCarthy. "What our discovery might make you think is that though the density is a whole lot higher than we thought, maybe these surveys are missing most of the quasars. I think that's unlikely, but it's certainly possible."

Osmer also doesn't think that earlier surveys necessarily missed these high-redshift quasars. "There are obviously some high-redshift quasars out there but not in very great numbers. Searches made earlier in the decade that failed to find them at faint magnitudes are not necessarily



A Serendipitous Slit University of California doctoral candidates Patrick McCarthy and Mark Dickinson took this spectrogram to learn about the environment surrounding the radio galaxy 3C 441. They also netted the second-most distant object in the universe, quasar Q2203 +292, which just happened to fall in the slit opening. The slit of the spectrograph, shown as it was oriented the night of the discovery, is 2 arcminutes long by 2 arcseconds wide; total sky coverage within the slit is 1/54,000th of a square degree. Photo courtesy of Patrick McCarthy.

invalidated by the [recent] results."

According to Osmer, the same 30-square-degree area of sky in which the Cambridge team found its quasar and Osmer found his may contain as many as 1,500 lower-redshift quasars. As it stands now, a sky total of eight quasars is known with redshifts above 4. Because quasars are believed to be spread uniformly across the sky, the low-redshift species are probably the most plentiful.

Astronomers believe that the cutoff in the number of quasars at higher redshifts may represent the period when galaxies across the universe were born — the so-called epoch of formation. The most successful model of galaxy formation, known as the cold dark matter (CDM) model, predicts that the first galaxies formed no earlier than a redshift of 5, or over 12 billion years ago. Although the existence of quasars with redshifts greater than 4 does not conflict with this theory, the discovery of several quasars at redshifts greater than 5 would disqualify the model.

High-Redshift Galaxies

Even as a large number of high-redshift quasars were being racked up last year, a group of astronomers was pursuing another quest: the most distant galaxies. The most distant normal galaxies known lie 4 billion to 6 billion light-years away, which means their light originates from a time when the universe was about one third its present age. Astronomers want to observe even younger normal galaxies to see if the properties of these galaxies differ significantly from those of the Milky Way and other normal galaxies in our neighborhood. Unfortunately, normal galaxies aren't as luminous as quasars, and active galaxies with their characteristic bright cores aren't considered normal; consequently, normal Milky Way-type galaxies

> ***"What our discovery might make you think is that though the [quasar] density is a whole lot higher than we thought, maybe these surveys are missing most of the quasars."***
>
> ***— Patrick McCarthy***

Andrew Fraknoi

with very high redshifts are more difficult to find.

Harding E. Smith of the University of California at San Diego and his colleagues have devised a way of finding normal galaxies that are too distant and too faint to be seen with normal optical means. Smith looks for quasars that might be "back-lighting" galaxies that lie along our line of sight to the quasar. So far, he and his colleagues have come up with twenty cases in which they believe distant spiral galaxies happen to lie between us and more distant quasars. Smith reports that one of these galaxies has a redshift of 2.3, which corresponds to a distance of nearly 11 billion light-years, almost two times more distant than the previously most distant known galaxies.

Smith believes these "back-lit" high-redshift galaxies may reveal what conditions were like in young, normal galaxies that are perhaps passing through a stage our own Galaxy experienced 10 billion to 15 billion years ago. Astronomers have already learned that some of these high-redshift galaxies are forming new stars at a rate not much higher than the rate observed in the Milky Way, which suggests that galaxies may evolve into recognizable structures at an earlier age than astronomers thought.

"Quasars are pathological objects," said Smith. "They are something in which some huge explosion has disturbed what may be a normal galaxy, or there may be something else unusual going on inside them. As a result, quasars have been very difficult to interpret in terms of the evolution of normal galaxies.

"The important aspect of our research is that it finds not pathological objects but selects galaxies like our Milky Way, which we presume to be normal galaxies."

Primeval Galaxies

High-redshift galaxies, if we can find them, may help answer questions about the formation and evolution of normal galaxies. But is it even possible to observe galaxies that contain stars that are just beginning to shine?

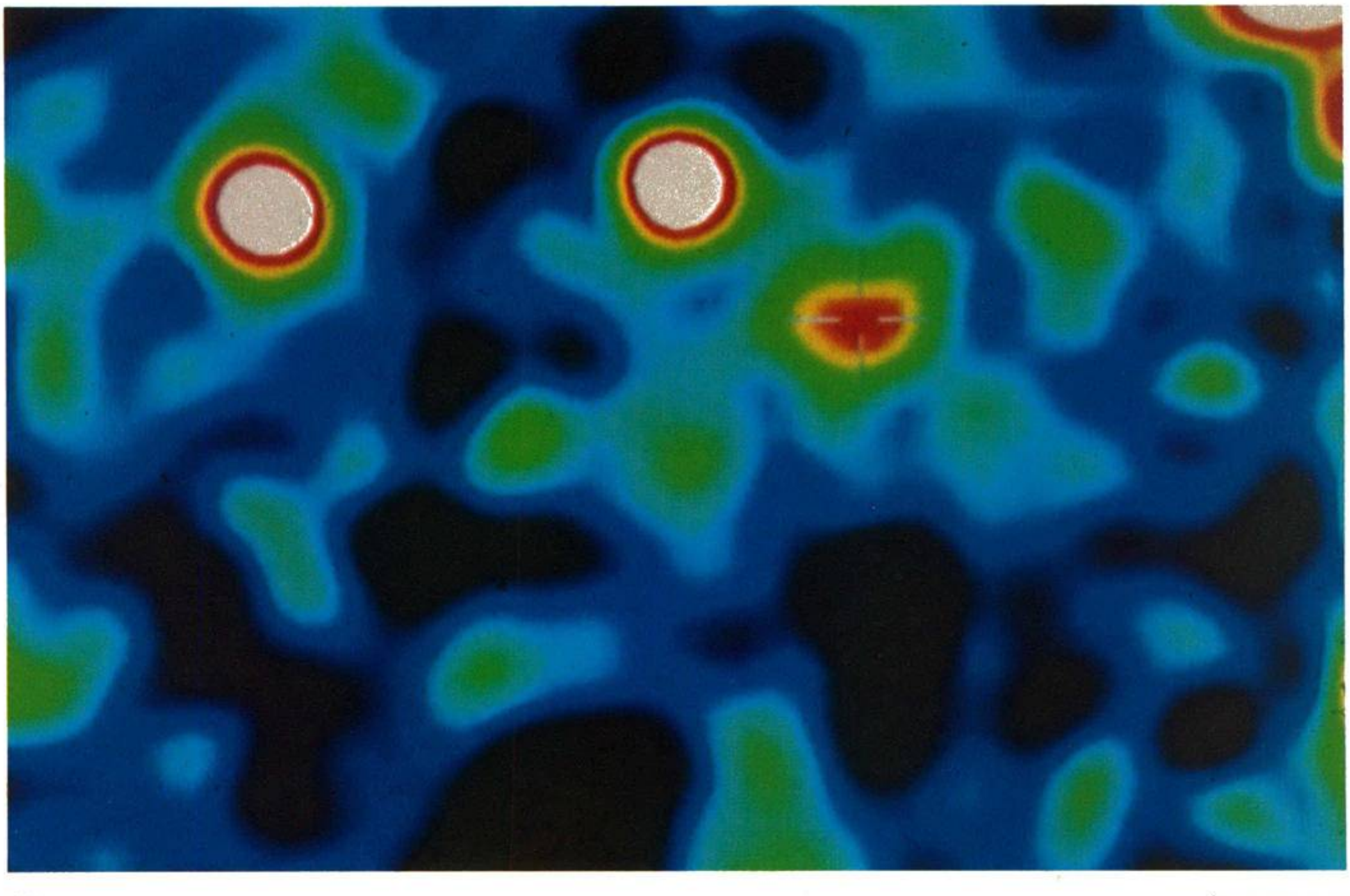
Theoretically, yes. Certain galaxy formation models predict that primeval galaxies should be very bright and visible during their early star-forming stages, even though they are at immense distances. These same models also predict that there should be a lot of these galaxies, in fact as many as one thousand or so per square degree of sky!

Despite these confident predictions, optical searches for this large population of primeval galaxies have been unsuccessful. However, astronomers from the University of Arizona announced at last January's meeting of the American Astronomical Society in Austin, Texas, that two infrared sources they recently detected may fit the primeval galaxy profile. Richard Elston, a member of the University of Arizona observing team from Steward Observatory, said the redshifts of these primeval galaxies may be in excess of 6. The distance to objects with this high a redshift would be well over 12 billion light-years.

"To explain these objects, you need a very luminous galaxy, one rapidly making the bulk of its stars," Elston said. "But these are also very red, which implies they are at more than redshift 6. We still have to confirm this preliminary work, but we think it is interesting."

The discovery was made with a powerful infrared camera developed by Elston's colleague Marcia Lebofsky

A Primeval Galaxy? **If astronomers confirm that the red object indicated with cross hairs in this computer-generated image is a star-forming galaxy over 12 billion light-years away, the current theories of galaxy formation will have to be revised. The two white spots at the upper left of the primeval galaxy candidate are nearby stars. Photo courtesy of the University of Arizona.**



Rieke. The heart of the camera is an array of more than four thousand infrared detectors; the camera is capable of gathering data 10,000 times faster than the old detectors.

Last spring astronomers Elston, Marcia Rieke, and George Rieke attached the infrared camera to Steward Observatory's 61-inch telescope located in the Santa Catalina Mountains north of Tucson and surveyed two randomly selected 8-square-arcminute areas of sky: one region was near the north galactic pole and the other was in the constellation Lynx. The camera observed at a wavelength of 2 microns, which is about the longest wavelength practical for ground-based observations of deep space. Elston and the Riekes then made follow-up observations at optical wavelengths with a charge-coupled device on Steward's 90-inch telescope at Kitt Peak. The optical observations provided a broader baseline of wavelengths; hence they yielded more information about the nature of these objects.

The objects they found, though 10,000 times fainter in the infrared than the background sky, were very luminous and very red. These objects couldn't be quasars because they were not points of light but extended 5 or 6 arcseconds across. Other possible explanations for these objects, such as nearby dusty galaxies, compact groups of high-redshift galaxies, or galaxies going through a "post-starburst" phase, were also considered doubtful. Elston believes it unlikely that about one thousand of these types of objects exist per square degree of sky, which is the number predicted by galaxy formation models.

"All I would claim is that these are excellent candidates for primeval galaxies. It's like a good mystery novel. For the first time we have some good clues, but we don't know 'who dunnit' yet. It's very exciting."

— Richard Elston

Andrew Fraknoi

"Given just the number of objects we see, their brightness, and their red color," said Elston, "the most plausible explanation is that these are galaxies just forming the bulk of their stars in this huge, luminous burst."

If quasars approaching redshifts of 5 were challenging the best model of galaxy formation, the confirmation of one thousand galaxies per square degree of sky at redshifts greater than 6 would virtually blow it out of the water. "The cold dark matter model would go by the boards," said Steve Warren, "because [the model states] you can't form galaxies that early on in the age of the universe."

McCarthy agreed. "If you find lots of galaxies with redshifts of 5, then that tells you that the bulk of the galaxies formed very early, and that pretty much wipes out a lot of theories of galaxy formation."

Without a doubt, Elston's announcement raised a lot of eyebrows at the Austin meeting, but although many astronomers are excited and intrigued by the observations, they want to see more data.

Margaret Burbidge, the esteemed British astrophysicist from the University of California — and one of the first to join the ranks of quasar observers in the 1960s — was polite but succinct: "I think it's very interesting. I'd like to see it confirmed."

McCarthy said he would be surprised if Elston's objects turned out to be galaxies with redshifts higher than quasars. "Quasar redshifts have always outpaced galaxy redshifts," McCarthy explained, "and it's always easier to find the higher-redshift quasars because quasars are so much more luminous. That doesn't mean the galaxies aren't out there. It's a question of finding them and getting redshifts for them. That's the difficult part."

Osmer thinks Elston's infrared sources "are probably the best primeval galaxy candidates we have, but that's all. They might turn out to be something close by or they may turn out to be something more exotic."

Even Elston is cautious. "All I would really claim," he said, "is that these are very excellent candidates for primeval galaxies. It's like a good mystery novel. For the first time we have some good clues, but we don't know 'who dunnit' yet. It's very exciting."

The next few years of redshift sifting should prove fruitful, even if theorists have to return to their computers and search among the integers for a new theory on galaxy formation. There are many other questions that only a study of these high-redshift objects may be able to answer. For example, are quasars precursors of galaxies or do they represent some other stage in galaxy development? Why are the chemical compositions of redshift 4 quasars similar to those with redshifts less than 1? Do quasars cluster into strings or filaments like galaxies? And can we learn anything about the intergalactic medium using high-redshift quasars as probes?

The prime goal in searching for high-redshift objects is not to find another "most distant" quasar or to tear down established theories but to discover a way of understanding the relationship of quasars and galaxies and the early universe. Predictably, more theories will be dismantled than erected before an answer is found. But that's as it should be. After all, mankind has been studying the universe for only a few thousand years, while the light from the most distant quasar has been traveling through space for about 12 billion years. We've just opened our eyes to the distant past.

ASTRONOMY
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The First Astronomy Novel

"We have known of literary novels, sporting and dramatic novels, law and politics novels, musical novels, but an astronomy novel — never." So wrote one reviewer of Thomas Hardy's unusual story of romance, *Two on a Tower*, published in 1882. This was the first novel to use an astronomical background and the first to cast an astronomer, Swithin St. Cleeve, as the protagonist. The other major character is the slightly snobbish Lady Viviette Constantine. Why cast these two in the world of astronomy? Hardy told critics that his aim had been to "set the emotional history of two infinitesimal lives against the stupendous background of the stellar universe."

To write this novel, Hardy researched the subject thoroughly. He read everything he could find on astronomy. But soon Hardy's astronomical research encompassed more than just reading. Late in 1881 he visited the Royal Observatory in Greenwich to see professional astronomy in action. His guide was W. H. M. Christie, the new astronomer royal. Hardy was lucky, because had he requested a visit earlier, the imperious Sir George Biddell Airy, Christie's predecessor, would have turned down the request of a novelist, even one of Hardy's fame.

Throughout his novel Hardy demonstrated his competence in handling astronomical technicalities. He told his readers, for example, that about three thousand stars were visible at one time to the naked eye, that the fixed stars moved through space "with incredible velocities," that Leo and Virgo each contained a close double star, that the Coalsack in Cygnus had a counterpart in the southern sky, and that diffraction rings were seen as perfect circles in a properly aligned refractor.

However, literary critics saw the book in a different light. "In spite of felicitous passages," noted the *Cambridge Guide to English Literature*, "the novel cannot be regarded as more than a pot-boiler." And a contemporary review in the political weekly *Spectator* complained, "There is not, from beginning to end, a single gleam of probability in the whole plot."

The first nine chapters of *Two on a Tower* tell the story of St. Cleeve and his search for fame through observing variable stars. Lady Constantine's notorious husband has been hunting lions in Africa for the past two years, which left his spouse "neither maid, wife, nor widow." One day she climbs a stone tower on their estate and discovers Swithin St. Cleeve observing the Sun through an altazimuth telescope. He had used the tower as an observatory for some time. With the brashness of youth the twenty-year-old tells Lady Constantine his ultimate aim is "nothing less than the dignity and office of Astronomer Royal" and that at night he observed "with a view to my great work on variable stars."

> Thomas Hardy said his aim was "to set the emotional history of two infinitesimal lives against the stupendous background of the stellar universe."

The lonely woman is attracted to the solitary astronomer and later returns to the tower for a promised telescopic tour of the heavens. During their long observing session Swithin reveals another yearning. "I hope to be the new Copernicus," he said. "What he was to the solar system, I hope to be to the systems beyond."

Lady Constantine, who by now trusts the young man, reveals a personal problem. She has received an anonymous letter intimating that Lord Constantine was seen in London and asks if Swithin will go there to find out if this is true.

"Personally I would go to the end of the world for you," he responded, "but I am preparing a work on variable stars. There is one of them which I have exceptionally observed and on this my great theory is mainly based. Now, to clinch my theory, there should be a sudden variation this week — or at least next week — and I have to watch every night not to let it pass."

"You are the most ungallant youth I ever met," said Lady Constantine, "but I suppose I must set it down to science." She offers to watch his star every night, so Swithin undertakes his London mission. He finds the man is not Lord Constantine, merely someone who resembles him.

Swithin monitors his star with an opera glass while in London. He believes a change in brightness took place on Sunday night, but he is not sure. Filled with anxiety, he hurries back to Lady Constantine only to find she neglected the star on two occasions. One of them was that critical Sunday night.

The stunned astronomer sadly reaches for his valise and, to his horror, drops a package he was carrying. While in London Swithin had spent his life savings on an achromatic objective for the equatorial telescope he intends to build atop the tower. He picks up the package and shakes it; what's inside makes a clinking sound. "Can it be mended?" asked Lady Constantine. "Mended? No, no!" is all Swithin can say.

Lady Constantine feels a surge of

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sympathy for the shattered young man. She orders a new objective so Swithin can complete his instrument. His task completed, he returns to her with a lugubrious announcement. His telescope is a failure.

Again Lady Constantine is touched by Swithin's misery. She will buy an equatorial telescope from the best optician in London and asks Swithin to describe his heart's desire. "It is a splendid instrument," he told her, "with an object lens of, say, eight or nine inches, mounted with its axis parallel to the Earth's axis, and fitted with graduated circles denoting right ascensions and declinations: besides having several eyepieces, a finder, and clockwork to make the telescope follow the motions of right ascension. Ah, an equatorial is a thing indeed!"

Though universally panned by contemporary critics, *Two in a Tower* introduced astronomy into popular culture, a theme that has endured since Hardy's day.

Workmen from Hilton & Pimm's establishment arrive at the tower to erect the telescope and enclose it in a dome that rolls on cannon balls. Swithin is enchanted. "I can see double stars in the Lion and Virgin where I only saw one before," he told Lady Constantine. "It is all I require to keep me going."

One day an elated Swithin rushes to Lady Constantine. "I have made an amazing discovery in connection with the variable stars," he exclaimed. "It will excite the whole astronomical world, and the world outside but little less. I had long suspected the true secret of their variability, but it was by the merest chance that I hit upon a proof of my guess. I said I would be the Copernicus of the stellar systems, and I have begun to be. Your equatorial has done it, my good, kind Lady Constantine!"

"Publish it at once in some paper," warned his benefactress. "Nail your name to it or someone will appropriate it — forestall you in some way." Swithin prepares three copies of "A New Astronomical Discovery." He directs one to the Royal Observatory, another to a prominent astronomer, and a third to the Royal Society. He also prepares a statement for the leading daily paper that gives the essence of his discovery.

His documents are too precious to be dropped in a post box, so Swithin sets out through the rain to a post office five miles away. On the way he stops at a bookseller to pick up the latest astronomical journals and then turns homeward, reading the journals as he goes. Hardy describes that return trip:

"On he strolled through the rain holding his umbrella vertically over the exposed page to keep it dry while he read. Suddenly his eye was struck by an article. It was the review of a pamphlet by an American astronomer in which the author announced a conclusive discovery with regard to variable stars.

"The discovery was precisely the discovery of Swithin St. Cleeve. Another man forestalled his fame by a period of about six weeks."

Hardy's book met as unglorious a fate as Swithin St. Cleeve. Universally panned by contemporary critics, *Two on a Tower* is today an almost forgotten literary work. Despite its failure, the story did accomplish one important task. It introduced astronomy as a theme into popular culture, a theme that has grown and endured since Hardy's day.

Kenneth Weitzenhoffer
Brooklyn, New York

Astrocamping at the 'City of Rocks'

Camping with a telescope — astrocamping — is not a new idea. But because clear views are often located in the most inhospitable locations, finding an amenable place to camp with the requisite unobstructed views of the whole sky can be difficult.

Fortunately the geologic forces that created City of Rocks State Park in southern New Mexico must have had the future stargazer in mind, because there's a unique selection of campsites with broad horizons.

City of Rocks got its name because sixty-foot boulders, tossed out onto the prairie by a cataclysmic volcanic eruption, look like buildings from a distance. Secluded among these pillars of stone are great astrocamping sites.

Southern New Mexico isn't graced with as many high mountain observatories as west Texas and Arizona are, but the area is superb for the amateur. The desert night air is dry and cool and the clarity of the atmosphere is so good you feel as if the stars are within your reach.

City of Rocks was a very comfortable spot for camping. During the day the light prairie breeze fluttered the leaves among the tent sites and kept me cool. I was tempted to doze in the shady nooks among the rocks and let the cares of bustling city life drift away.

The first indication of evening's approach was the birds bursting forth in song. Hummingbirds appeared in and around the trees and darted here and there to seek the nectar. It was a treat to sit quietly as the Sun slipped down the sky and watch these little avians with their brilliant feathers perform the magic of stationary flight.

Even dinner amid the gathering shadows at City of Rocks was memorable. The sage turned varying shades of green as the sky changed from blue to gold to purple at the approach of evening. Sampling the cuisine of southern New Mexico seemed like the right thing to do. A truly local dish like barbecued pork, pinto beans in ranch sauce, spicy salsa, and blue corn tortillas was perfect amid the splendid scenery and fresh air.

As twilight deepened into night, I sipped my coffee and prepared for the evening's observations. The first stars popped into view, and within minutes the cool desert evening was studded with the jewels of the night sky. When you align your telescope with Polaris here, though, you often have to double check that the "right" Polaris is in the finder scope. In the clear desert atmosphere under such a panoply of stars it's easy to be misled.

I observed galaxies, nebulae, and double stars — all those deep-sky objects you could never hope to see from the city suddenly became easy to observe in these dark skies.

Nowhere is the evidence of the changing motion of the constellations, caused by the Earth's rotation, more evident than at City of Rocks. In the deep darkness of the high desert the constellations rise and set with a motion primitive man must have wondered at and modern man rarely notices. Here, without smog or light pollution, you can see the stars from the instant they peek over the eastern horizon until they disappear beyond the western rim. You can actually sense the Earth's rotation as the early evening stars blink out below the

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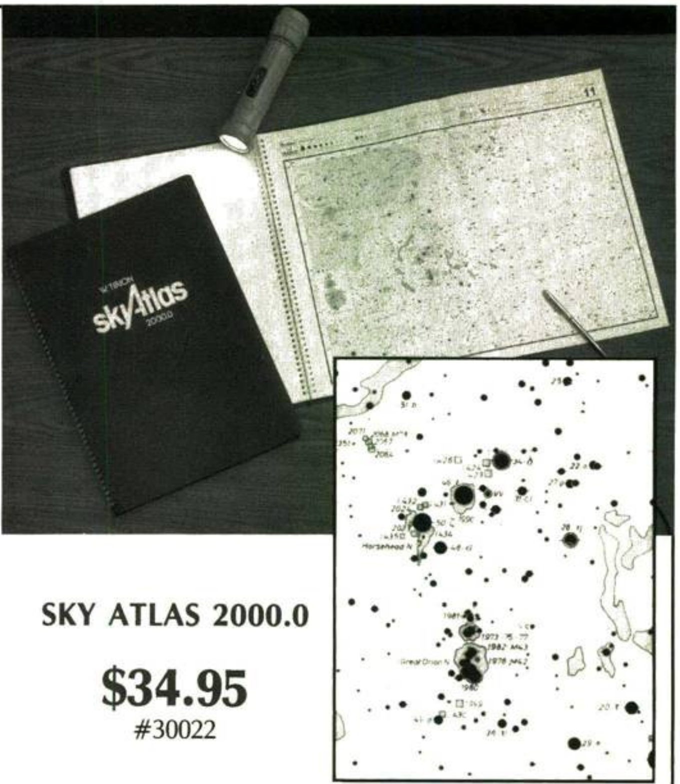

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horizon.

Under these conditions observing is impressive. Yet I was forced to push away from the eyepiece just to look up and gasp at the sheer majesty of the starry sky. The sounds of animals and birds far out on the prairie only added to my feeling of being dwarfed by the heavens and made me realize how tenuous man's hold on the planet is. There's nothing more humbling to the confident city dweller out under the desert stars than hearing the coyote's wail and feeling the soft rush of the night breeze.

Once the correct alignments and settings were made, I turned to the evening's entertainment. One by one I observed galaxies, nebulae, and double stars — all of those deep-sky objects you could never hope to see from the city suddenly became easy to observe in these dark, clear skies.

The bright smudges of the galaxies were easy to discern from adjacent stars with a pair of binoculars or a small telescope. If you don't own a telescope, just lie back in a folding chaise lounge with your binoculars — it's a great show!

The difficulty is deciding when to stop observing and enjoy the quiet of the desert night from inside a downy sleeping bag. Dawn comes early, and with it the first calls of the birds as the starlight is washed away by the Sun.

John Bushby
Boston, Massachusetts

Reshaping Public Attitudes toward the Space Program

To counteract the negative public opinion that followed the *Challenger* tragedy in January 1986, I started a small space advocacy group in central Illinois called the Central Illinois Space Group.

I expected an uphill battle. But I discovered that instead of a negative attitude toward NASA, there is a lot of respect for NASA and the American space program. Really, almost too much respect.

Over the course of a little more than a year our group put on many events to educate the public about the U.S. space program. We set up displays and answered questions, got NASA programs on the local cable TV system, were interviewed on local TV and radio, and wrote frequently for local newspapers. We helped start a Young Astronauts chapter at the local planetarium and arranged to write planetarium shows.

Through these activities we learned how the public perceives the space program and how to work with those perceptions to promote the space program.

At several of our events children, who had probably been born about the time of the first shuttle flight in 1981, asked their parents questions about our *Apollo* era displays. "What's that?" the child would say, pointing at a lunar module. The parent would say, "That's how we go to the Moon." Not how we *went* when we still could, but how we *go*.

The American public seems to think the space program is healthy, when actually it has been crumbling for almost twenty years. At one event a father told his son that we no longer had Saturn V rockets "because now our rockets are bigger and better." I had to correct the father in front of his child. "No," I said, "we do not have bigger rockets. And it's debatable whether what we have now is better. The Soviet Union has bigger rockets, if what you mean by 'bigger' is 'more powerful.' In fact, Soviet rockets are bigger than anything we've ever had or will have for many years."

Not the way to make friends and influence people, but someone has to say it. We need to dispel a little of the blissful ignorance out there.

> The public has been sold on the idea that our space program is a success story; those of us more familiar with space know it is still only a potential success.

The local media seems bent on perpetuating this misconception. When I wrote an article about *Challenger* a year after the accident, I stated baldly that we were all to blame for the tragedy, that one of our responsibilities as Americans is to make sure worthwhile government programs don't die of neglect.

My meaty comments were watered down into a digestible broth. And affixed to this article was a spurious headline that said NASA would magically (or at least without visible public effort) rise again. This type of optimism only hurts the space program. People have to be made aware of a problem before they will be motivated to speak out.

The public has been sold on the idea that our space program is a success story; those of us more familiar with the space program know it is still almost entirely a potential success. The key to making the public understand this is distancing yourself from space.

There are many things a space enthusiast can do to become a space advocate. Having a space group behind you is a great advantage. Use your imagination — what I list here are only a few possibilities.

If there is a planetarium or a university physics department nearby, ask for help in starting your group.

To find members, go to astronomy clubs, HAM radio clubs, and model rocketry clubs. I think many people see space as entertainment, not as something they can have an impact on, so you will probably have only a small core of active members in your group.

Local libraries and schools will probably be eager for you to set up displays. Make these displays exciting and easy to understand. Remember that you're competing with TV and movies on space, where budgets for graphics and special effects are enormous and science is usually nonexistent.

Get members of your group to write letters to the editors of local papers. You'll be noticed fast. Write on any aspect of space, but be sure to be accurate and sober sounding. It's crucial for establishing your all-important credibility. (Letters to the editor also have the advantage of being cheap.)

Contact your local cable TV system to see if it can add NASA Select TV to its offerings. If it can't — ours couldn't — get the cable system to show taped NASA programs. Because it is a government agency, NASA can't promote itself, but it can be very cooperative if you want to promote it.

Show an interest in kids. If a Young Astronauts chapter exists in your area, get involved in it. Its commander will probably be glad to make use of your space knowledge. If you have no Young Astronauts chapter nearby, encourage a teacher to start one.

Starting a space group can be rewarding, perhaps more rewarding than you think. As I spoke about space at a father and son banquet, I wondered if one of the children fidgeting on the floor might grow up to colonize Mars or become a politician that goes to bat for future space programs. It is possible that your pro-space activities might eventually lead others to the stars.

David S. F. Portree
Winter Park, Florida

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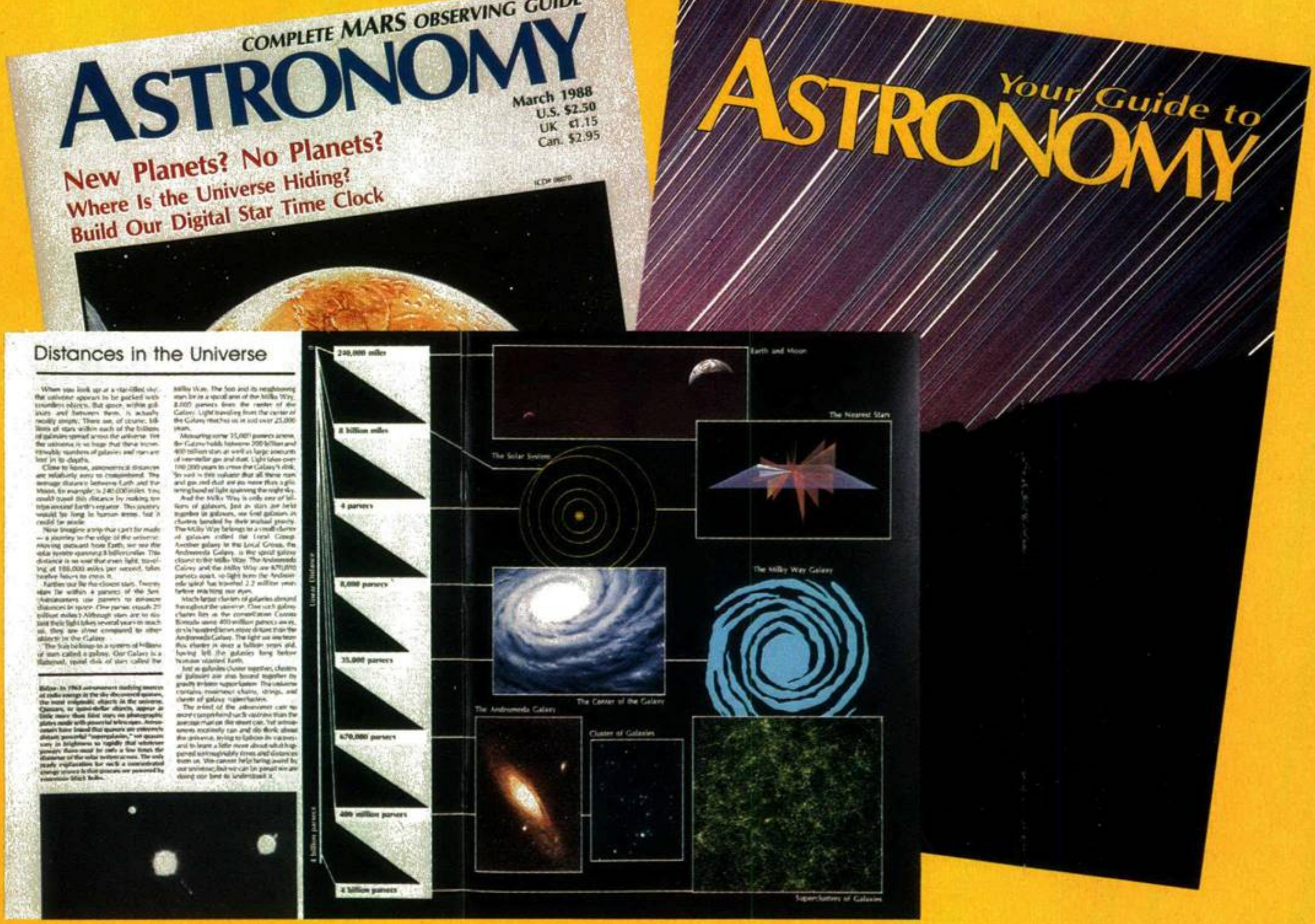
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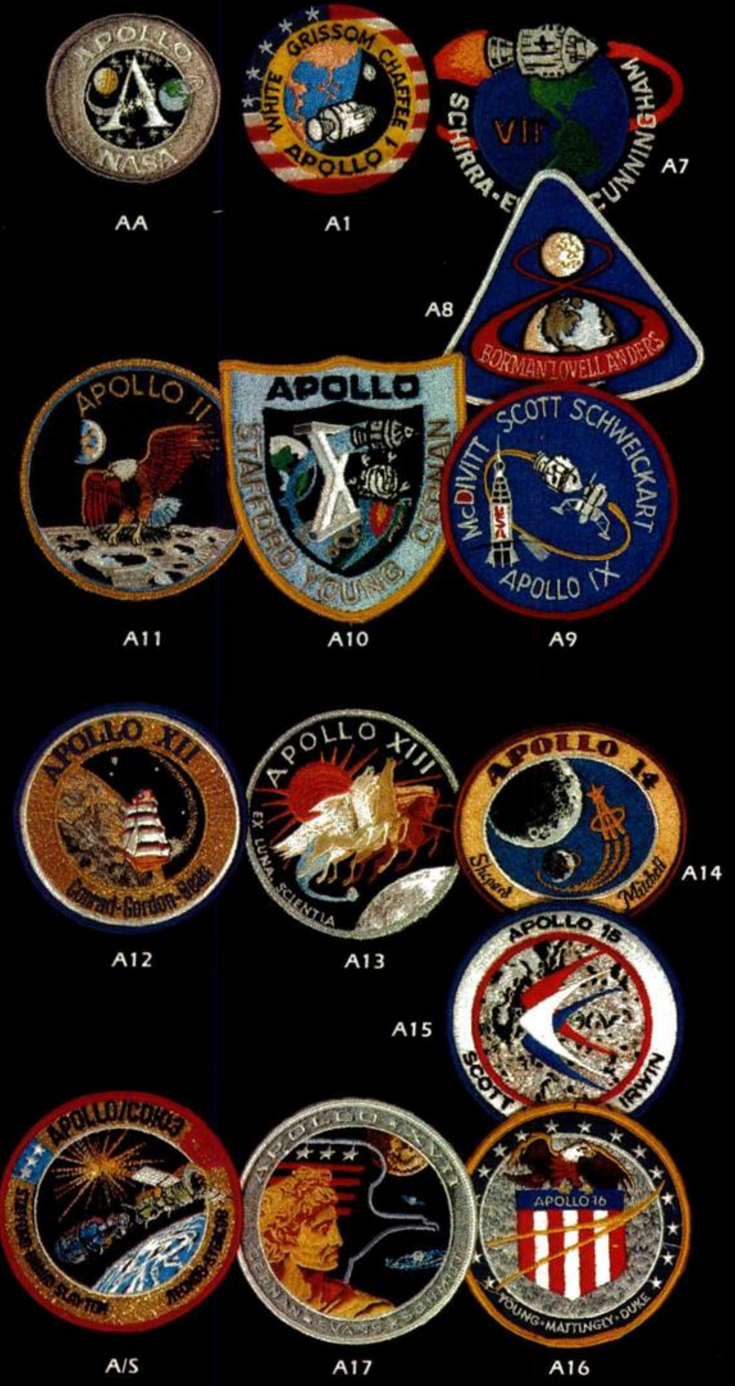
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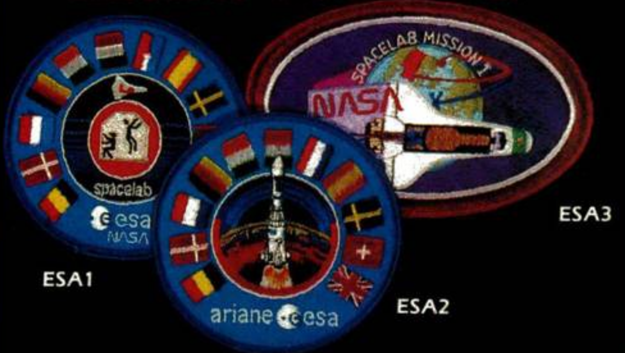
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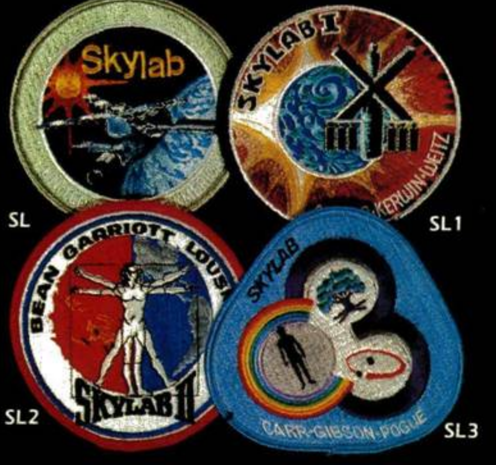
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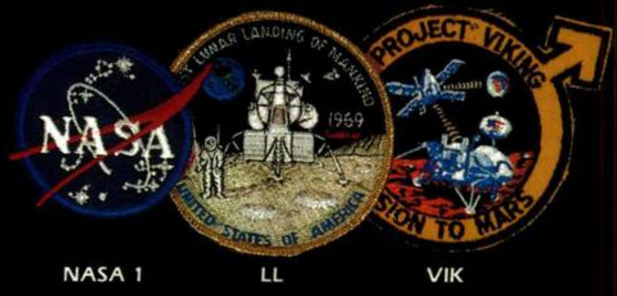
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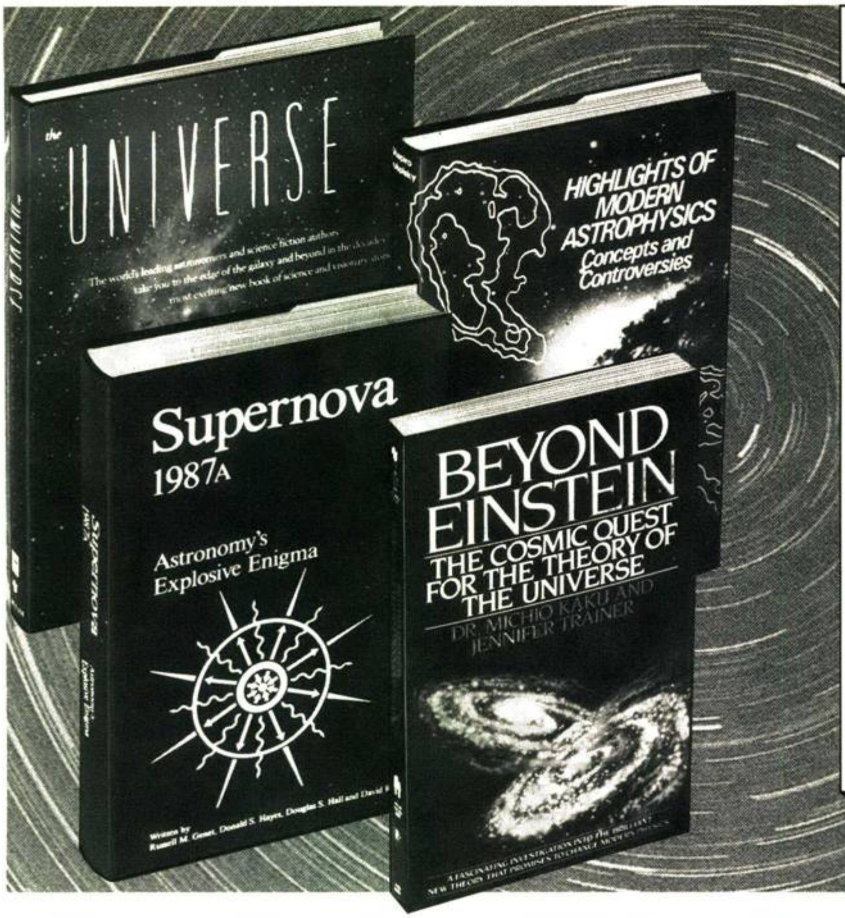
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ASTRONOMY

In Focus

Uranometria 2000.0 Not a 'Disappointment'

Sir / Brian Skiff's review of *Uranometria 2000.0* (Astronomy Reviews, February 1988) does a disservice to the many telescope owners who finally can own and use an atlas capable of showing detailed telescopic fields and an abundance of deep-sky objects. Having used *Uranometria 2000.0* in the field on a number of clear nights, I can state without reservation that this is the most manageable atlas of its kind. Its coverage exceeds anything I've ever had, its size is quite convenient, and its bound pages end the frustrations of chasing loose sheets in the wind. The markers at the borders of each chart make rapid movement around the sky easy, and the index charts at the back of the volume are most helpful.

To state, as Mr. Skiff does, that the atlas is "a disappointment to the dedicated observer because it mirrors the faults of the catalogs on which it is based" is scandalous, not only in its flippant dismissal of a major work that is likely to become a classic in its own time but also in its insulting implications for many of us who spend long hours observing in light-polluted skies near station wagons filled with scopes, charts, electric socks, food, and the like.

Mr. Skiff is certainly a dedicated and productive observer, but those dark nights under Arizona skies, the access to the rich bounties at Lowell Observatory, and the dismissal of so many of us as "nonserious" observers suggests a certain loss of contact with *our* versions of reality.

Sam Storch
North Merrick, New York

Schiaparelli's 'Channels'

Sir / I want to clarify what Frank Apsi-Ridolfo wrote about Italian astronomer Giovanni Schiaparelli in "The Primal Fear: Are We Alone?" (Forum, December 1987). Schiaparelli never stated that the *canali* he saw on Mars were artificial.

In the review *Natura ed Arte* (Nature and Art), February 1893, Schiaparelli wrote: "The network of 'canali' was determined originally by the geological state of planet and slowly elaborated itself in the course of centuries. You do not need to suppose the work of intelligent beings."

The misunderstanding, which has been stated many times before, originated from the English translation of the Italian word *canali,* which means both canals and channels.

Alfredo Brogioni
Castiglione del Lago, Italy

More Ado about Dew Caps

Sir / Since I read Harry Hammond's "Build a Heated Dew Cap for Less than $10" (Equipment Atlas, November 1987), I have been thinking about replacing the resistors with a single wire that could be easily attached to the inside of any dew cap with duct tape.

It turns out that heating wire from an electric blanket is well suited to the purpose. The wire from the blanket I used has a resistance of 0.18 ohm per inch. (This may vary from blanket to blanket.) It gets hand-warm with a current of 1 amp. For a dew shield of a 10-inch SCT, use two full turns of wire to get a resistance of 13 ohms yielding a current of 0.97 amp.

For a dew shield of an 8-inch SCT, these values using three full turns are 15.2 ohms and 0.82 amp. However, any resistance can be selected by adding a fraction of one-half turn and then folding the wire back to the terminal. The wire can be stripped by holding it over a burning match and stripping off the metal shield with your fingernail. This will expose the core and wrapped-around resistance wire.

It is difficult to solder the wire. Use a small terminal block and attach the core of it like any other wire. Washers with two flat sides will prevent the screws from shearing the wire.

For 120 VAC operation use a 20- to 30-watt power transformer with a secondary of 12.6 volts (Radio Shack) for safety.

Hans J. Mueller
San Francisco, California

Sir / Can you stand another suggestion about heated dew caps? Aluminum flashing, available at hardware stores and building supply outfits in various widths at nominal prices, can be used to easily form tubes. Duct tape, also available at the same stores, sticks to metal tenaciously and should hold the flashing together.

Finally, insulated heat tape (for warming water pipes), which is available at plumbing supply houses, hardware stores, and building supply places in the colder parts of the country, comes in various lengths and is a good source of heat if 120 volts are used.

To make the dew cap, simply blacken the inside of the flashing with flat black spray paint, wrap the tube with heat tape, and plug it in. Extra care should be taken to protect the cord inside the heat tape from chafing, but otherwise these supplies seem safe to me.

Jere T. Murray
Homer, Alaska

Rabbit-in-the-Moon

Sir / My son Tommy sees the same Rabbit-in-the-Moon little Elizabeth sees in "An Eclipse through the Eyes of a Child" by Joseph T. Hepworth (Forum, February 1988).

Perhaps Elizabeth, as well as other children, would like to know about the Japanese folklore surrounding that rabbit. His name is Shiro, and he is the samurai of the Moon. His story is explained in *The Rice Cake Rabbit*, translated by Betty Jean Lifton.

David Parrott
Memphis, Tennessee

Optical Blemishes Worth the Risk?

Sir / I am a first-time telescope buyer and noticed that many retailers offer telescopes with "cosmetic blemishes" at a reduced cost. The retailer claims the telescopes may "have a tiny optical 'sleek'" and that "optical performance is absolutely not affected." Is this true? What other cosmetic blemishes exist and is a telescope with a blemish worth the price?

Matt Kowalewski
Shrewsbury, Pennsylvania

— A dinged tube is something you can probably live with. Telescopes don't have to be pretty to work effectively. But buying a scope that the retailer claims has some sort of "optical blemish" could be risky. Although a few sleeks (tiny, almost invisible scratches) would not harm performance, you should not agree to buy any optically "defective" telescope without a thorough test, because if something is really wrong, you'd have no recourse.

Slipping behind the Moon

Sir / In "Earth and Moon Together" by Hank Brandli (October 1987), the caption for astronaut Jack Schmitt's photo of the crescent Earth reads: "as the fragile blue globe slipped behind the Moon's limb." How can this be? Earth could only have slipped behind the Moon's horizon if the Moon rotated on its axis, and it doesn't.

Jerry Petranek
Sierra Vista, Arizona

— The Moon wasn't moving, but the astronaut was. His spaceship was in orbit around the Moon.

In Favor of the 'CAT'

Sir / After I read David J. Eicher's "The ATI 'CAT': The Wave of the Future (Equipment Atlas, December 1987), I bought a CAT and successfully fitted it to my telescope.

The CAT is advertised the way George Allen indicated in his letter (In Focus, February 1988): "See one hundred galaxies per hour!" But the speed at which you are able to locate an object is important only if you have a limited number of hours of clear sky, as we have in England. With the CAT my time can be spent doing exactly what Mr. Eicher recommends: "seeing what it's all about."

I applaud the initiative of companies like ATI. They may be in it for the profit, but if this increases my enjoyment of observing and that of others, good luck to them. The night sky does not belong, as Mr. Allen suggests, to the curious observer who has a small scope. The sky belongs to no one and anyone who takes the trouble to look, and each of us is free to do so by whatever means he chooses to employ.

Peter Warburton
Oldham, Lancashire, England

Corrections to the Star Time Clock

Sir / I have just completed the circuit described in "Build ASTRONOMY's Star Time Clock" by Irwin Sternberg (Equipment Atlas, March 1988), and I have a few comments for others who plan to build this interesting device.

The middle left photo on page 46 shows the correct placement of the connections to the clock, but the wires are not identified and the text includes some incorrect information.

The 60-hertz clock (labeled "CP") should be pin 25 (not pin 27) and is labeled "50-60Hz input" on the clock schematic diagram. The 50/60-hertz SELECT (labeled "50/60 SEL") should be pin 26 (not pin 25) and is not identified on the clock schematic.

Also, the Positive Supply Voltage 5-15 Volts DC (labeled "A") and the Supply Voltage Return (labeled "B") connections are not obvious from the schematic diagram.

The photo is correct: the "A" connection is made to the plus ("+") side of the clock's capacitor C1 (470 MFD). The Supply Voltage Return "B" wire should be connected to the minus ("−") side of the same 470 MFD capacitor (C1), which is located near the resistor R5 (120K ohm) on the clock board.

Mark R. Mehall
Aloha, Oregon

Behind the Scenes

Expect the Unexpected

While it may be something big (like the chance to see a supernova) or something small (like a night of superb seeing), you should always expect the unexpected in astronomy.

In February the sky in Wisconsin isn't clear very often. But when the sky is clear, the weather is cold and the seeing is usually terrible. The stars almost crackle they're twinkling so hard. On nights like these the Moon has that "underwater" look, and the images of the planets are mush.

But not always. The unexpected occurred February 22, the night Mars passed closest to Saturn and Uranus in the predawn sky. Because it was crystal clear in the early evening, I set up my 10-inch Dobsonian on the driveway. I expected terrible seeing — but when I looked up at the stars, I noticed they weren't twinkling.

I plugged in a low-power eyepiece and looked at the Orion Nebula. I switched to high power; the air was rock-steady. Beside the four familiar bright stars in the Trapezium I spotted two tiny points of light — the fifth and sixth members of the Trapezium. Then I *knew* it was an extraordinary night; poor seeing usually wipes these fainter members out.

I swung the scope over to Jupiter: the cloud belts stood out clean and crisp. Venus, then slightly gibbous, displayed faint markings on her brilliant disk.

I didn't expect the sky to stay clear, and I certainly didn't expect such fine seeing to persist. But late that night, before going to bed, I set the alarm clock.

When it woke me, the sky was just starting to brighten. From a window I saw Mars and Saturn shining together. The thermometer read −2. I went outside.

Saturn was as sharp as a steel engraving in the frost-covered telescope and surrounded by a retinue of pinpoint satellites. I swung the telescope to Mars and popped in a high-power eyepiece. The tiny, gibbous, orange disk was crisp, and I glimpsed the south polar cap and some gray-green markings on the disk. I found the greenish disk of Uranus easily only a fraction of a degree from Mars. It was great: three planets in three minutes.

There's no lesson in this story but the obvious one: If you don't look, you won't see. Expect the unexpected — and keep looking.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

Reviews

The Rosetta Stone of Meteor Craters

Coon Mountain Controversies by William Graves Hoyt, (University of Arizona Press, 1987), ISBN 0-8165-0968-9, hardcover, 443 pages, $40.

As you stand on the rim of Meteor Crater in Arizona, the Sun's rays carry that ultraviolet sting you find only at high altitude, and every shadow is deep and dark as it echoes the blue sky overhead. A breeze warmed by sunlit rock blows past you into the vast natural amphitheater. The upper wall drops away at your feet in a treacherous slope of talus that eventually flattens to meet the rubbly bowl-shaped bottom. The scene is extraordinary. Yet for anyone who relishes a sense of irony, it's the peaceful silence of Meteor Crater that speaks most clearly.

Known variously as Coon Mountain, Coon Butte, Crater Mound, and now Meteor Crater, this depression in the empty, cloud-swept Colorado plateau of northern Arizona is the best preserved impact crater on Earth. It was made about 50,000 years ago when a 300,000-ton piece of iron and nickel came down from the sky, smashed through the desert floor, and came to a halt several hundred feet below the rock surface. As its enormous kinetic energy was converted to heat, shock waves raced out into the surrounding rock and the meteorite virtually disappeared in a blinding flash of light and vapor, leaving a yawning pit four thousand feet across and a thousand feet deep. Only fragments, most weighing no more than a few pounds, survived the impact to litter the land around the crater and to collect in the crater's slowly accumulating infill like poppy seeds in a cake.

The story of how both geologists and astronomers came to recognize this bowl for what it is makes an absorbing tale, very well told by Hoyt.

Meteor Crater entered geology's literature in 1891. That year an Arizona sheepherder named Mathias Armijo showed some meteoritic iron

The origin of Meteor Crater in Arizona was attributed to a volcanic steam explosion before the crater's real nature was recognized.

he had found to the sheep camp's cook, a man appropriately named Craft. Craft took the fragments to an Albuquerque mining firm, and on the strength of the firm's preliminary assays, borrowed some money and skipped town.

The samples he left behind, largely iron but with other interesting minerals including diamonds, soon found their way to a well-known Philadelphia mineralogist named Arthur Foote. The meteorites so intrigued Foote that he visited the crater himself. He then described the samples and the crater at a conference attended by Grove Karl Gilbert, at that time chief geologist of the U.S. Geological Survey.

Immensely well respected, Gilbert had a few unorthodox professional beliefs, among them that the craters on the Moon had been formed by the impacts of meteorites. Gilbert's ears pricked up when he heard Foote tell of finding meteoritic iron next to a large crater in northern Arizona. Organizing a field party on short notice, Gilbert was en route to the Arizona Territory two months after Foote gave his report.

Gilbert studied the topography and geology of the crater while a colleague made magnetic survey traverses. Through these studies they attempted to locate the main mass of the meteorite that Gilbert was sure lay below the crater's bottom. Other members of the team scoured the landscape and collected many meteoritic fragments.

After two weeks of work, however, Gilbert was frustrated. Nothing in the magnetic survey indicated that the main meteorite was present, and tests of the instrument's sensitivity proved that a nickel-iron mass of reasonable size should be detectable. So, reluctantly abandoning a model he had privately set great store on, Gilbert chose an alternative: that the crater had been made by a great steam explosion touched off when volcanic heat encountered ground water. Their fieldwork over, Gilbert and crew packed up and returned to Washington. Gilbert published his report five years later.

Enter an energetic mining engineer named Daniel Moreau Barringer. Puffing a cigar on the porch of a Tucson hotel in 1902, he heard an intriguing tale about a crater on the northern plateaus. After doing some research, Barringer concluded — Gilbert's report notwithstanding — that the crater had been made by an iron meteorite and that the main mass was still buried in the crater. If the meteorite was there, he reasoned, it had to be big and mineable. Fired with entrepreneurial zeal, Barringer promptly staked claims on the crater, hit up the first few of a long line of investors, and set to work.

He and a companion closely examined the crater, finding many small nickel-iron pieces and noting the gigantic quantities of rock flour (pulverized quartz) that filled the bottom of the basin and covered the areas immediately surrounding the rim. The meteoritic irons couldn't simply be coincidental, Barringer felt, and he was sure no ordinary volcanic explosion could have reduced sandstone grains to so fine a consistency that they didn't feel gritty even when ground between one's teeth.

Barringer drilled a few holes in the center of the bowl, thinking the meteor had gone straight in. As the drill bit worked steadily deeper, it penetrated many hundreds of feet of rock flour, then broken and crushed rock, and finally undisturbed sandstone. No big meteorite — but numerous tiny fragments.

Barringer's published report raised the interest of geologist George Merrill, whom Barringer soon wheedled into conducting a study on the crater. Initially skeptical, Merrill soon convinced himself that some great "concussion" had happened; for besides the rock flour, he found significant quantities of fused quartz, a substance that requires temperatures far higher than volcanic action provides. In the

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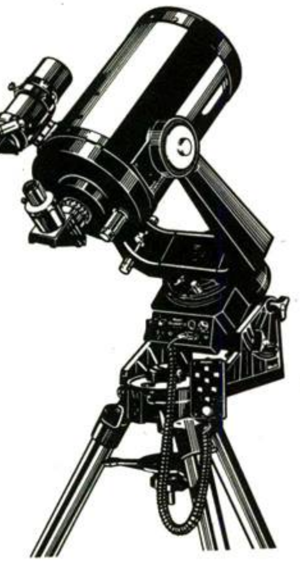

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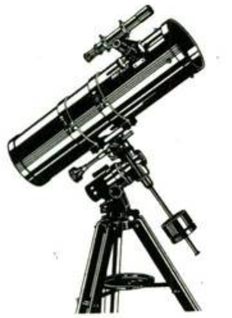

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years that followed, Barringer shifted his focus from the center of the crater to the south wall, where he thought the meteorite had come to rest. Barringer also escorted many astronomers and physicists of the day (most notably Henry Norris Russell of Princeton) through the crater, and almost all came away attesting to their belief that the crater was impact-formed.

Thus a curious consensus began to emerge in the 1910s and 1920s: geologists tended to believe Moon craters were caused by impacts and that craters on Earth were volcanic. Astronomers meanwhile pooh-poohed lunar impacts but thought very highly of terrestrial ones!

In a sense the crater's history for the next quarter-century centered largely on Barringer's ceaseless efforts to discredit Gilbert's report, establish the crater's impact origin, and raise money to find and mine the meteorite. It is a story too long and involved to summarize here — Hoyt spends almost half the book on it. But two clear results emerged from the debates: impacts have happened repeatedly on Earth, and the destructive potential of an inert body moving at celestial velocities is immense.

This last conclusion was brought forth by mathematician-astronomer Forest Ray Moulton only a few weeks before Barringer's death in 1929. It crushed Barringer's hopes completely, for it implied that the meteoritic mass was smaller than everyone had been assuming (not worth mining, in other words) and that it was vaporized almost completely in the impact. Barringer's sons continued to raise money for excavating meteorite fragments, but the goal was now scientific. The best return they ever got on the countless thousands Barringer spent drilling and sinking shafts came from the tourism the crater's growing fame engendered.

Ironically, while the report by Moulton was such a blow to Barringer, it also marked the turning point in scientific acceptance of the impact model. Holdouts (particularly in the U.S. Geological Survey) didn't come around for many years, but by the early 1930s the burden of proof had shifted and advocating a volcanic origin became a lot more difficult.

After Barringer's death, Hoyt wraps things up fairly quickly. He traces the work of those who confirmed Moulton's model and extends the discussion to include the debate on lunar crater origins. By 1950 geologists' greater experience and familiarity with explosion craters (thanks to World War II, Korea, and nuclear tests) had put the impact-explosion model on firm theoretical ground. When Ralph Baldwin wrote his seminal *The Face of the Moon* in 1949, his skillful advocacy of impact cratering pointed out the widespread role of high-velocity collisions in the history of the solar system.

The story of Meteor Crater tempts you to reduce the whole affair to some catch phrase like "Great Scientist Gets It Wrong and Impedes Progress." But this denies a much more complex reality. Gilbert's opinion certainly carried great weight, especially within the U.S. Geological Survey, where it was elevated almost to sacred writ. But Gilbert himself had turned to the steam explosion model only very reluctantly and carefully hedged his conclusions by noting that a lot of data was still unknown — cautions that other scientists with axes to grind often overlooked.

In the years before Gilbert's death in 1918, several mutual colleagues got word privately to Barringer that Gilbert had come to accept the crater's impact origin. Yet the controversy-shy Gilbert never publicly recanted. And Barringer would often fly into a rage when someone would quote Gilbert's report against the impact model because, infuriatingly, he could exhibit no proof the great man had changed his mind. (Interestingly, Hoyt thinks Gilbert deliberately refused to confirm Barringer's work openly but offers no reason except Gilbert's well-known loathing for scientific disputes.)

Also working against a simplistic version of the controversy is that Barringer didn't always play squeaky clean. Remember, he was financing his digs by selling shares of stock to people who, along with Barringer himself, hoped to become fabulously rich by mining a meteorite. At one fiscally awkward point Barringer suppressed a pessimistic report by Russell (on the body's probable size) so the directors of the company wouldn't lose their resolve. In short, Barringer's clear financial interest could give any scientist fussy about proprieties ample grounds to question both Barringer's fieldwork and his intentions.

In any case, what surprises me is the apparent inability of everyone involved to imagine the sheer force of the impact and the subsequent destruction of the meteorite. Gilbert matter-of-factly assumed the meteorite would still exist, so when his magnetic survey gave a null result, he looked to steam explosions. Barringer got the impact right, but he spent one borrowed fortune after another chasing the main mass of the meteorite, which always lay just beyond the last bore hole.

It wasn't until almost four decades after the initial survey of the crater that anyone seems to have put pencil to paper and worked out whether you could even *expect* to find the meteorite, let alone pinpoint the meteorite's probable resting place!

If we stand on the crater's rim and look back on the debate with today's space age eyes, it's hard to see what the shouting was about. Meteor Crater's origin is transparently obvious; see any aerial photo of the crater. But as Hoyt acknowledges in this excellent book, we who live in the megaton age carry fewer illusions about the destruction that follows a big bang.

— Robert Burnham

New Products for Telescopes and Astrophotography

SureSharp astrophotography focusing device, (Spectra Astro Accessories, 8726-D South Sepulveda Boulevard, Los Angeles, CA 90045), $115.

One of the most frustrating problems for astrophotographers is achieving accurate focus. Used with care, SureSharp ends those problems and provides a simple and certain way to focus every frame perfectly.

I tested SureSharp with my 6-inch f/5 Newtonian astrocamera — the same photographic system I used to take pictures last summer for the article "SR-V 3200: The Superfilm from Konica" (Photography in Astronomy, November 1987). Before using this device, I focused on the ground-glass portion of the focus screen of my old screw-thread Pentax camera body. While I'd managed to get fairly sharp star images for most of my tests, my first test roll of hypered SR-V 3200 displayed soft images because of poor focus, so I couldn't use any of those pictures in the article. I don't know whether my eyes were tired, I got sloppy, or what, but SureSharp makes such accidents easy to avoid.

SureSharp is a device that substitutes for the body of your camera when you focus the telescope. Once the telescope is focused, you remove the SureSharp and place the camera on the correctly focused system. I found switching from the SureSharp to the camera the trickiest part of the operation, because attaching the Pentax screw thread involves rotating the heavy camera body three full turns and introduces the danger of shifting the focus in the process. This would not be a problem with any modern bayonet-mount camera body.

The SureSharp consists of two parts: a custom connector that you must attach to your telescope's focuser or camera adaptor, and a viewing assembly that replaces the camera body. Attaching the custom connector to my Meade camera adaptor took just a minute. I loosened three tiny screws with the jeweler's screwdriver sup-

The Ronchi screen inside the viewing assembly of the SureSharp camera focuser helps focus images exactly at the film plane.

The Cheshire collimating eyepiece by Tectron Machine Corp., in the focus assembly of a telescope. Photos by Richard Berry.

plied, popped the connector on, and tightened the screws.

The viewing assembly slips over the custom adaptor and attaches to a taper ring on the adaptor with two nylon thumbscrews. The assembly contains a Ronchi grating at the corresponding exact position of the film in your camera. To focus, you view a bright star through the Ronchi screen. If you see dark and light bands, you adjust the focus until the star "nulls out" and appears as a perfectly uniform gray image. You then remove the viewing assembly and attach the camera. The instructions supplied with the unit explain exactly what to look for when focusing.

If you're serious about deep-sky astrophotography, SureSharp is the answer to the fuzzy-star blues. It's easy to use, works like a charm, and isn't expensive when you consider how frustrating badly focused pictures are.

Collimating Tools, (Tectron Machine Corp., 2021 Whitfield Park Avenue, Sarasota, FL 34243), set of three tools, $90.

If a Newtonian telescope isn't performing up to snuff, the first thing to check is its optical alignment, or collimation. Large-aperature short-focus Newtonians are especially sensitive to alignment errors, and carefully collimating the mirrors almost always improves optical performance.

The collimating tools made by Tectron fit into the focuser just like an eyepiece. By examining the optical system through them, you can tell whether the focuser, secondary mirror, and primary mirror are lined up or not. If they're a little off, you can quickly set them right.

Tectron's collimating set includes a sight tube used to set up the focuser and secondary mirror, a Cheshire "eyepiece" for aligning the primary mirror, and an autocollimator for precise final alignment. All three of these tools are machined from aluminum, black-anodized, and precise —infinitely more precise than homebuilt sight tubes and collimation devices usually are. Each set includes a comprehensive manual that tells you how to use the tools.

I tested Tectron's collimation tools on two of my telescopes, a 10-inch f/6 Dobsonian and a 6-inch f/5 photographic Newtonian. Both were fairly well aligned before I started, but in both cases the ten minutes I spent tweaking the alignment resulted in noticeably better images.

I recommend these tools to any individual who wants topnotch performance from a Newtonian reflector and to all astronomy clubs. Once you've seen what your telescope *can* deliver, you'll never again settle for an image degraded by coma.

Photo-Clear Lens Cleaner, optical cleaning cloth, (HP Marketing Corp., 16 Chapin Road, Pine Brook, NJ 07058) 6-inch by 6-inch cloth, $6; 12-inch by 15-inch cloth, $18.

Photo-Clear is a cloth made for cleaning optical surfaces in cameras, but it works well for cleaning telescope lenses, corrector plates, and eyepieces. This cloth is extraordinarily soft and silky, looks almost metallic, and drapes very heavily. (It resembles the cloth you'd expect to see draping an alien in a science fiction movie.)

According to the manufacturer, the cloth is a patented nylon-polyester material with no chemical additives. I examined it under a microscope; the threads in the weave are made of loose bundles of very fine fibers. These fine fibers apparently trap dust, grit, and grime and lift them off the optical surface. I did not see any loose fibers with the microscope.

I tried Photo-Clear on coated and uncoated lens surfaces. Used dry with a very light touch, the cloth removes dust in just one or two passes. It only takes a little pressure to remove fingerprints. (Because rubbing a lens with anything could scratch the glass, never use more than the lightest pressure.) Water spots and dew stains required a liquid lens cleaner (such as Formula MC, reviewed below) before they came off. I saw no trace of the linty residue that most cloths leave when I use them to clean lenses.

I did not try the Photo-Clear cloth on any aluminized surfaces — these scratch far too easily. For these, I recommend the traditional running water, dishwashing detergent, and a cotton swab with no pressure. For coated and uncoated lens and eyepiece surfaces, however, Photo-Clean cloth seemed to do as well as lens tissue for wet cleaning and was much better in lifting off dust and grime when used dry.

Formula MC, Multicoated Lens Cleaner, (Peca Products, Janesville, WI 53545), one-ounce bottle, $1.99.

Put a drop of Formula MC on your eyepiece eye lens, wipe gently with lint-free optical tissue (or Photo-Clean cloth), and the lens will be clean. Two or three drops will clean a small refractor lens; five or six drops suffice to remove all but the biggest smudges from a Schmidt corrector.

Formula MC's advantage over water, even distilled water, is that it leaves no residue on the lens surface when it evaporates. Whatever this cleaner contains, however, dissolves the fatty acids in fingerprints on corrector plates and removes the nose grease that finds its way onto eyepiece lenses.

Formula MC appears to work well for the important cleaning jobs in amateur astronomy. I recommend extreme care in cleaning any coated lens or Schmidt corrector and no more cleaning than absolutely necessary. If you must clean, however, Formula MC works a lot better than plain water and Kleenex, distilled water and clean cotton rags, breath condensation and a handkerchief, or (heaven forbid!) dry scrubbing with a paper towel.

Hypered SR-V 3200 film, (Lumicon, 2111 Research Drive, Livermore, CA 94550), twenty-four-exposure 35mm film, $13.95.

At $13.95 a roll, hypered SR-V 3200 isn't cheap. However, for about sixty cents a shot, you're using the fastest color film speed available today. Fine grained it's not, but exposures that record all the nebular detail you'll ever get run a mere 5 minutes in a 6-inch f/5 Newtonian, and a 1-minute exposure records considerably more detail than a 15-minute exposure on unhypered 400 ISO film.

The film arrives by airmail in a sealed container with beads of desiccant to keep the film environment dry. Don't open the container — just pop it in the freezer until four hours before you're ready to use the film. It's best to shoot the whole roll in one night — not an impossible feat because twenty-four 5-minute exposures total only two hours. A three-hour session should suffice. Process your exposed film the next day.

I reviewed SR-V 3200 at length in the November issue of ASTRONOMY, both unhypered and experimentally hypered by Lumicon. I found it to be a rather grainy film that nevertheless offers astrophotographers the chance to obtain exciting color images in less time than ever before. The hypered SR-V 3200 Lumicon now offers is both faster and better color-balanced than the first few experimental rolls were. For easy-to-guide, short-exposure color astrophotography, nothing can touch hypered SR-V 3200.

— *Richard Berry*

Technical Planetary Textbook

The Space-Age Solar System by Joseph F. Baugher, (John Wiley & Sons, 1988), ISBN 0-471-85034-9, hardcover, 452 pages, $33.45.

Depending on your knowledge of physics, geology, and chemistry, *The Space-Age Solar System* may or may not be for you. The author suggests that his book could double as an introductory college text on planetary astronomy or as a reference for the armchair astronomer who has little or no background knowledge in the subject.

But who is the real audience of this book? I believe that when readability and content are considered, the true slant of the book is toward the college textbook market. Certainly, as a textbook this work should be well received because it is about as up to date and thorough as a book on the solar system can be. However, that doesn't necessarily make it an equally acceptable work for the armchair astronomer.

The first of the book's five parts covers introductory information on the makeup of the solar system — from the Sun's core to the outer boundaries of our planetary system. Tables, charts, and graphs help explain solar activity, the Sun's rotation, and solar atmosphere and wind. The book also compares old and new ideas about how the solar system works, based on the vast amounts of information sent back to us from recent space probes. The coverage of early solar system theories and the pioneering scientists who developed those theories — such as Ptolemy, Copernicus, Kepler, and Newton — is thorough and readable. Baugher also touches upon possible future explorations, such as the proposed unmanned probes to the Sun in the 1990s.

Part two treats the Earth from the perspective of the new knowledge we have gleaned about the other planets in the solar system. We first look at Earth's magnetic field, motions, and orbit, as well as continental drift theory. Then Baugher addresses the atmosphere, the greenhouse effect, and the development of Earth and its biosphere since the crust first cooled 3.8 billion years ago. Here the contrasts between Earth and the other planets — especially when you consider the life-promoting aspects such as the evolution of oxygen on Earth — really drive home the point that our planet is unique in the solar system.

The Moon and a survey of the inner planets round out part two. Each chapter covers the high points of planetary research. Findings from various space probes are presented, and theories about conditions of the planets during the early solar system are also discussed.

Part three covers Jupiter, Saturn, and their moons and rings. Baugher opens the section by describing Jupiter's vital statistics, including what we know about the planet's internal structure and the "weather" in the belts and zones that band the planet. This chapter ends with a discussion of the dynamics of Jupiter's enormous magnetosphere, which contains 400 million times more energy than Earth's magnetosphere. Baugher covers Saturn in much the same way he covers Jupiter, except that he devotes about eight pages to Saturn's ring system.

Uranus, Neptune, Pluto, comets, and the Nemesis theory — which proposes that the Sun has a dark companion star that comes near the Sun every 26 million years and brings a lethal rain of comets down on the planet — comprise part four. Meteors and meteorites, including types and origins, and solar system evolution make up part five.

A treasure house of information on the planetary probes is presented in tabular form in Appendix A, but the remaining appendices, which cover such areas as the various solar system elements, properties of the Sun and planets, and the isotopic abundance ratios in the planets, probably won't interest many armchair astronomers. These lists are worthless if you do not understand the relationships or the ranking of importance of the information in each appendix. Except for Appendix A, the nonstudent will gain little from the appendices.

On the positive side the discussions flow easily from topic to topic, and the writing is clear and generally interesting. The diagrams are simple yet rich in information. And I especially liked the scale drawings of each planet compared to Earth. The observer who wants to know more about what he is seeing in his telescope will find more than enough information here. But for the beginning amateur or nontechnical student, the sometimes dense technical content may be slow going if not inapplicable. This book clearly belongs in the classroom, where it will undoubtedly make a worthy contribution.

— *Robert A. Garfinkle*

Astrophysics

Exploring the Universe with the IUE Satellite, edited by Y. Kondo, (D. Reidel, 1987), ISBN 90-277-2380-X, hardcover, 787 pages, $49.50.

The Invisible Universe: Probing the Frontiers of Astrophysics by George B. Field and Eric J. Chaisson, (Random House, 1987), ISBN 0-394-74278-8, paperback, 195 pages, $14.95.

Particle Acceleration and Trapping in Solar Flares, edited by Gerard Trottet and Monique Pick, (D. Reidel, 1987), ISBN 90-277-2609-4, hardcover, 233 pages, $64.

General

Cosmic Joy and Local Pain: Musings of a Mystic Scientist by Harold J. Morowitz, (Charles Scribner's Sons, 1987), ISBN 0-684-18443-5, hardcover, 321 pages, $18.95.

Darkness at Night: A Riddle of the Universe by Edward Harrison, (Harvard University Press, 1987), ISBN 0-674-19270-2, hardcover, 293 pages, $25.

Descartes' Dream: The World according to Mathematics by Philip J. Davis and Reuben Hersh, (Houghton Mifflin, 1986), ISBN 0-395-43154-9, hardcover, 321 pages, $12.95.

Extinction by Steven M. Stanley, (W. H. Freeman and Company, 1987), *ISBN 0-7167-5014-7, hardcover, 242* pages, no price given.

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The Newtonian Revolution by I. Bernard Cohen, (Burndy Library, Electra Square, Norwalk, CT 06856, 1987), paperback, 42 pages, $6.

Nebulae

Planetary and Proto-Planetary Nebulae: From IRAS to ISO, edited by Andrea Preite Martinez, (D. Reidel, 1987), ISBN 90-277-2517-9, hardcover, 290 pages, no price given.

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Principles of Plasma Diagnostics by I. H. Hutchinson, (Cambridge University Press, 1987), ISBN 0-521-32622-2, hardcover, 364 pages, $65.

Three Hundred Years of Gravitation, edited by S. W. Hawking and W. Israel, (Cambridge University Press, 1987), ISBN 0-521-34312-7, hardcover, 684 pages, $69.50.

Solar System

Cosmic Debris: Meteorites in History by John G. Burke, (University of California Press, 1986), ISBN 0-520-05651-5, hardcover, 445 pages, no price given.

The Evolution of the Small Bodies of the Solar System, edited by M. Fulchignoni and L. Kresak, (North-Holland Physics Publishing, division of Elsevier Science Publishing Company, Inc., 52 Vanderbilt Avenue, New York, NY 10017, 1987), ISBN 0-444-87035-0, hardcover, 307 pages, $90.25.

Status and Future of Lunar Geoscience, NASA SP-484, (Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001), 1986, 54 pages, no price given.

Space

Before Lift-Off: The Making of a Space Shuttle Crew by Henry S. F. Cooper, Jr., (Johns Hopkins University Press, 1987), ISBN 0-8018-3524-0, hardcover, 270 pages, $18.50.

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The Overview Effect: Space Exploration and Human Evolution by Frank White, (Houghton Mifflin, 1987), ISBN 0-395-43084-4, hardcover, 318 pages, $18.95.

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Gazer's Gazette

Observe the Naked-Eye Sky Glows

by Philip M. Bagnall

Some of the most beautiful and mysterious sights in dark skies are the naked-eye sky glows. The most familiar type of sky glow is the aurora, caused by the interaction of Earth's magnetic field with high-energy particles released by the Sun. Aurorae are seen most frequently from high-latitude locations.

More elusive than the aurora are the faint zodiacal light, the zodiacal band, and the gegenschein. These three types of sky glows occur when sunlight is reflected off dust particles in the inner solar system. Which type of glow you see depends on how close or how far away from the Sun you look.

All these sky glows are visible with the naked eye, but they are a challenge to see. However, once you know what you're looking for and when and where to observe, you'll increase your chances of seeing these fascinating phenomena.

Everyone has heard of the aurora, which can take many shapes and forms, ranging from relatively faint and subtle displays to spectacular and colorful displays that cover much of the sky and glow in a variety of colors. The most common auroral forms are patches or glows, arcs, and bands. A patch or glow is a small luminous region of sky that shows no obvious shape or detail. It often occurs right along the northern horizon and is usually faint.

An auroral arc is an arc of light that spans the northern sky and is clearly separated from the horizon. It has a sharp lower border and its upper border usually tapers off gradually. A band is similar to an arc but lacks the arc's regular shape; the lower border is irregular and exhibits kinks or folds.

Each of the auroral forms can also be described according to its internal structure. A homogeneous arc or band, for instance, displays no internal structure and thus appears uniformly bright. A rayed arc or band shows a vertical ray structure. If many long rays develop in a band with a folded structure, the band's overall shape may resemble a huge celestial drapery floating in the sky. If you view a rayed structure from underneath, you may see a spectacular corona — a perspective effect that makes the auroral rays appear to converge to a point in the sky.

An intense auroral display often begins as a diffuse glow and then gets progressively more active. The faint glow develops into a brighter homogeneous arc lying higher in the sky and then rays start to form. Rayed arcs and bands, draperies, and coronas may come and go, pulsating in brightness as the aurora reaches its peak. The display may take anywhere from one to several hours to reach this stage, so it pays to keep a close watch on any aurora.

The brightness and color of the aurora vary as much as the shapes of the different auroral forms. At its faintest, the aurora is too dim to see with the naked eye, and many aurorae are close to the brightness of the Milky Way. At these levels the aurora appears white because your eyes are not sensitive enough to discern color in such faint objects. On the other end of the scale, the aurora can be bright enough to cast shadows. Colors are often apparent in brighter aurorae; yellow-green, blue, and red are the most common colors.

Observing an Aurora

An almost infinite variety of auroral displays awaits the alert observer. A spectacular display is actually hard to miss: if you're outside the brightness and movement of the forms will almost surely draw your attention toward the sky. But seeing the fainter displays requires diligence. Not only can a faint aurora be fascinating in itself, but the effort to find one may pay off in a big way. Because most major displays evolve from faint aurorae, the faint display you see at 10 p.m. could grow into a major auroral "storm" by midnight.

There are two key factors governing your chances of seeing the aurora, and both have to do with your location. If the glare of city lights brightens the sky, your chances of seeing a faint aurora are very poor. And, unfortunately, faint displays are more common than bright displays.

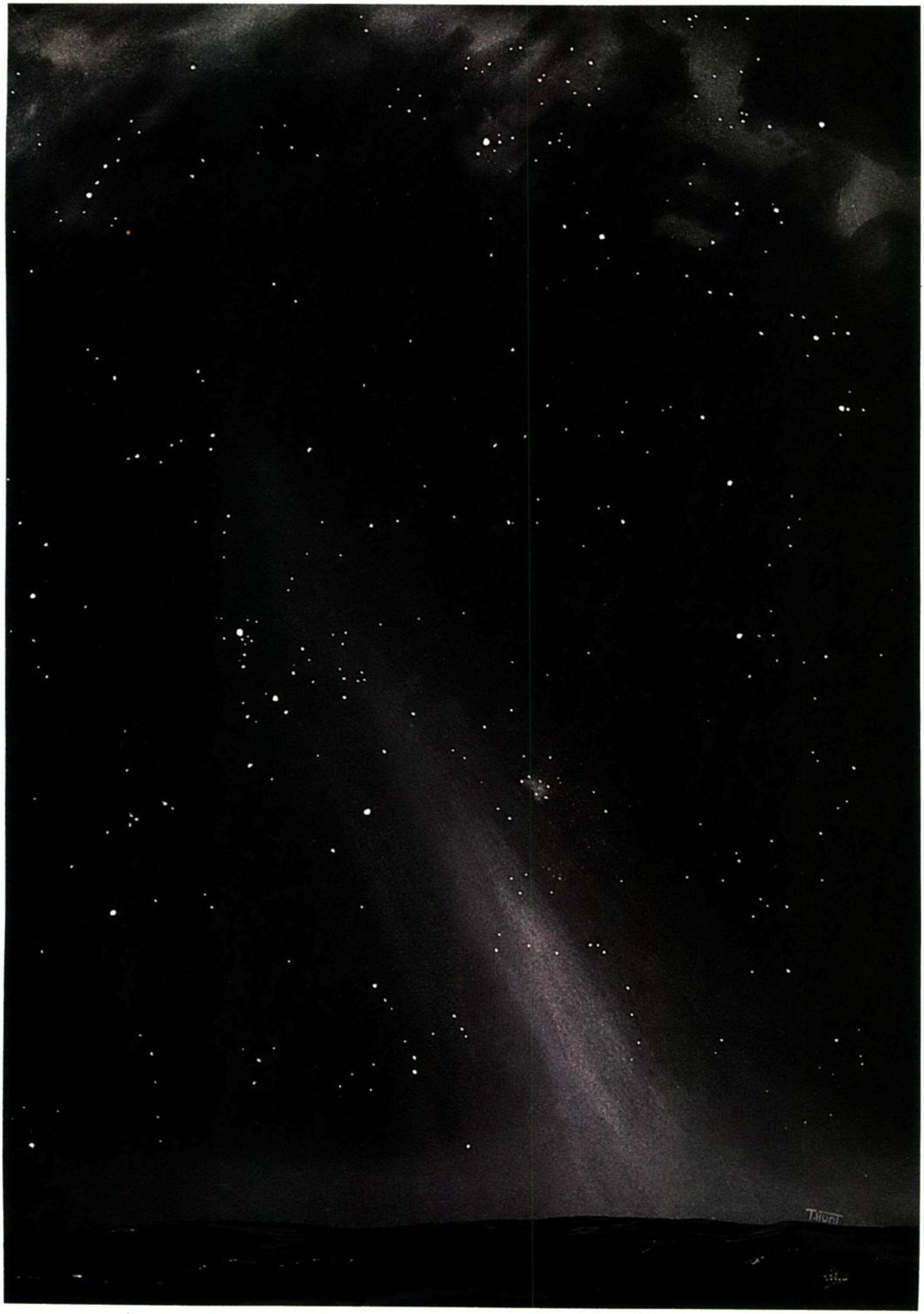
For the same reason, nights when the Moon is either faint or not in the sky are better than nights when the Moon is bright. Your best chance of spotting a faint aurora is during the two-week period centered on a New Moon. This summer New Moon falls on June 14, July 13, August 12, and September 11.

Your location relative to Earth's magnetic poles is also crucial to your observing success. Aurorae are most common in an oval-shaped region located between 20° and 25° from the magnetic poles. The chances of seeing the aurora diminish the farther you get from this band of greatest activity.

The north magnetic pole lies on Bathurst Island in northern Canada at a latitude of 77° north. For observers in the United States, this means your chances of seeing the aurora will increase if you travel to the northernmost United States, Alaska, or Canada. (See the map on page 49.) Based on long-term averages, you have an 80 to 100 percent chance of seeing the aurora each clear night in a band that runs from Barrow and Fairbanks, Alaska, across the Northwest Territories to central Hudson Bay, and continues through northern Quebec. People located in a band from Anchorage, Alaska, through central and southern Canada to Winnipeg, Manitoba, and then eastward can expect an aurora on the average of 20 to 40 percent of the clear nights. Even in the northern United States, from Washington across the Great Lakes to New England, the aurora can be seen 5 to 10 percent of the time, which corresponds to fifteen to thirty nights each year.

As you head farther south, your chances of seeing an auroral display diminish, but they never disappear. You can expect to see the aurora once or twice a year from as far south as Los Angeles or Houston.

Opposite page: The soft, white, and diffuse glow of the zodiacal light rises majestically from the western horizon on an early spring evening. All illustrations by Thomas L. Hunt.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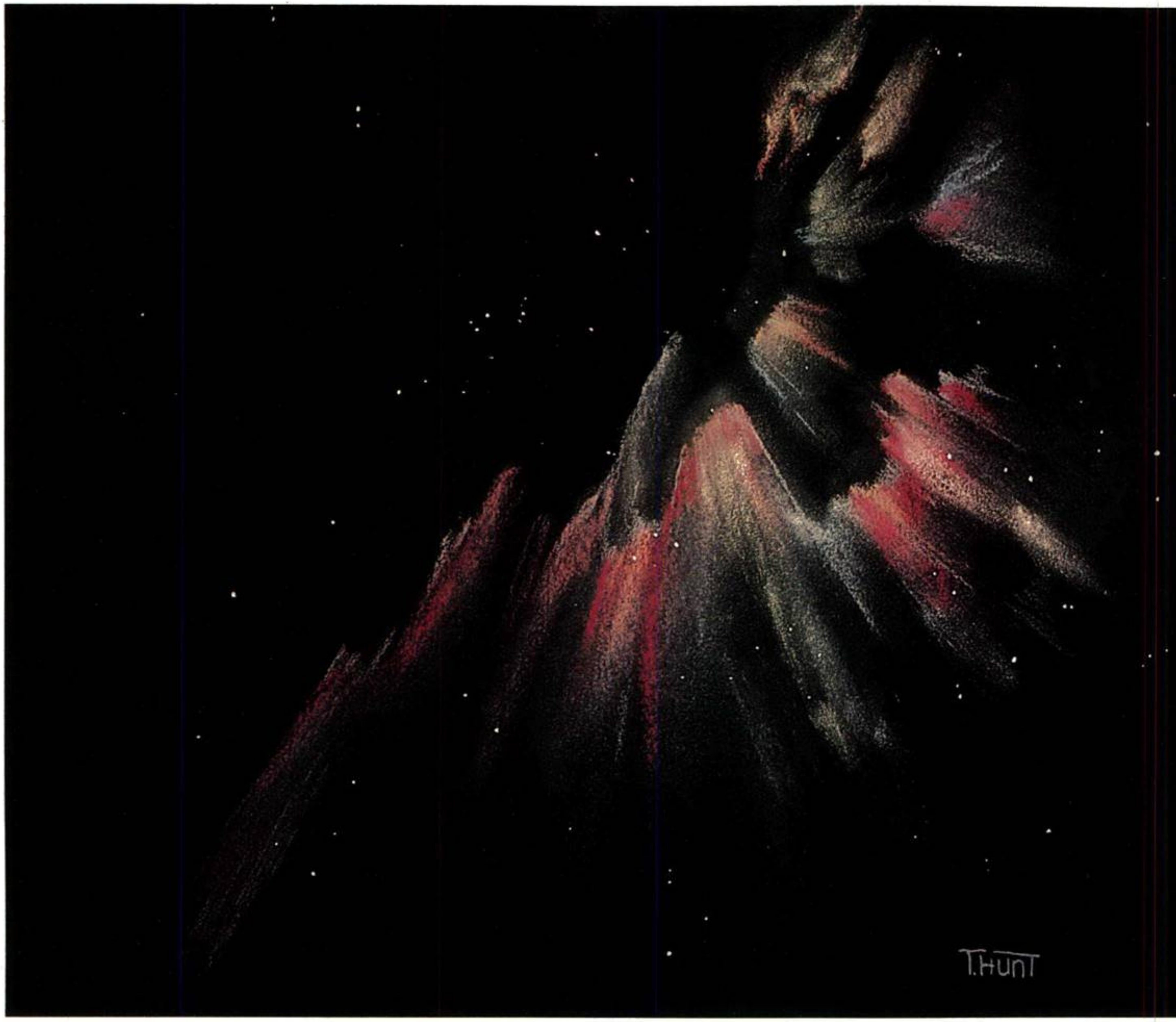
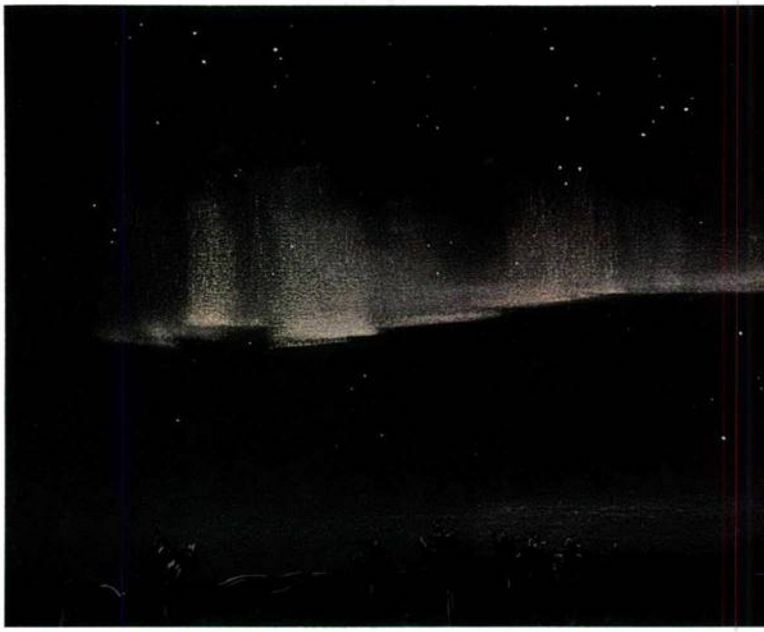
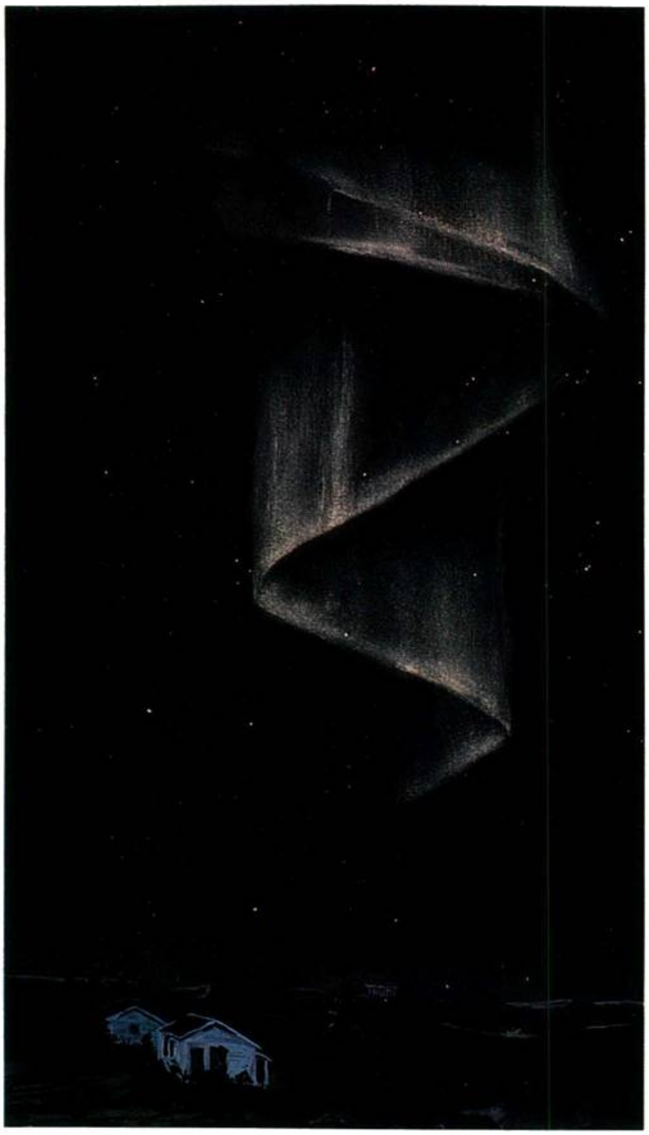


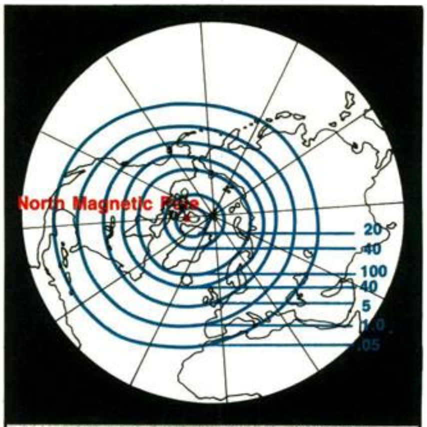
Above: One of the most impressive forms of auroral display is the corona. A corona is a rayed structure located overhead with all the rays appearing to converge toward a point in the sky.

Right: A subtle auroral arc stretches across the northern sky. Spanning distances that may reach 120°, arcs have well-defined lower borders that are clearly separated from the horizon.





Above: Auroral bands can take on a variety of fascinating shapes. Here a folded band has the appearance of a large curtain shimmering in the sky.



This map of the Northern Hemisphere shows the average percentage of nights on which an aurora can be seen, weather permitting.

And aurorae have even been seen from as far south as Mexico City. Remember, however, that these figures are for any auroral activity. Out of every ten aurorae there may be only one bright display.

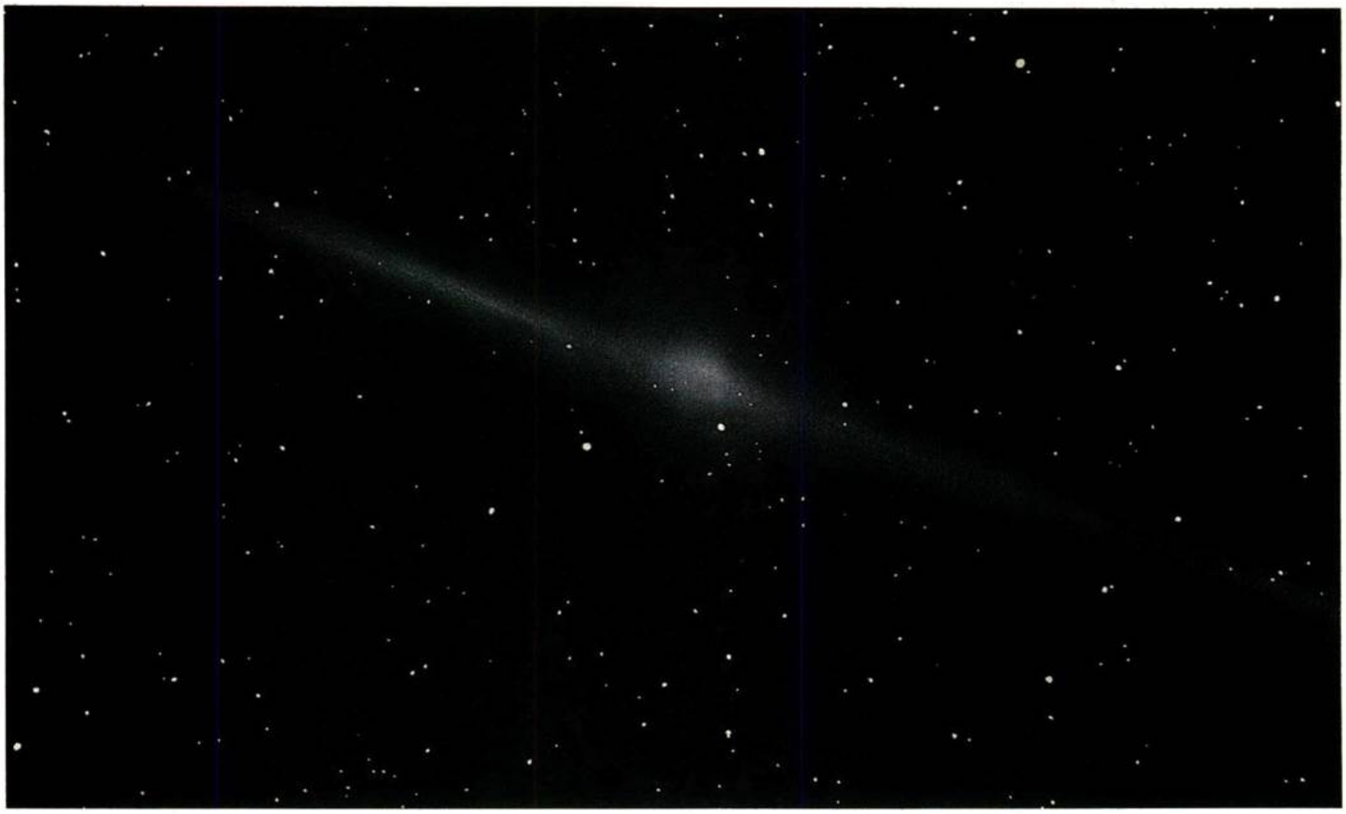
European observers generally see fewer aurorae than their North American counterparts. In northern Scandinavia your chances of seeing aurorae are 80 percent or better, but even such northern cities as London, Paris, and Moscow average aurorae on less than 5 percent of all nights. The aurora australis in the Southern Hemisphere is difficult to see from outside Antarctica because there is so little land in the best viewing regions. Southern Australia averages near 5 percent, but neither southern Africa nor South America averages more than 1 percent.

The Sun and Aurorae

The aurora is produced by the interaction of the Sun with Earth's upper atmosphere. The process begins with the stream of charged atomic particles — mostly protons and electrons — called the solar wind that flows outward from the Sun.

When the charged particles reach Earth, they are either diverted or trapped by Earth's magnetic field. The trapped particles spiral along the magnetic field's lines of force until the particles interact with atoms and molecules in the upper atmosphere, producing aurorae. The aurora occurs near the magnetic poles because that is where the field lines enter Earth's upper atmosphere. The aurora can occur as low as about fifty miles above Earth's surface and as high as a few hundred miles.

The different colors of aurorae are generated by different atoms and molecules in the atmosphere. The atmospheric atoms and molecules are excited by the solar wind particles, and when they return to their lowest energy levels, they emit light of a specific color. The yellow-green color common to many aurorae is produced by oxygen atoms, as are some red aurorae. Nitrogen molecules give rise to the blue-purple colors and are also responsible for



The zodiacal band and its brighter oval component, the gegenschein, can be glimpsed under an exceptionally dark sky. Try to observe these beautiful sky glows in the fall when they are high in the sky and far from the Milky Way.

some red color.

One of the biggest factors affecting the number and extent of aurorae is variations in the intensity of the solar wind. When the solar wind is especially strong, the number of energetic particles that reaches Earth is high and more aurorae occur.

The most important element governing the strength of the solar wind is solar activity. Solar flares release large amounts of gas suddenly, and if Earth happens to be in the path of this material, large auroral displays are possible. In fact, most of the great auroral storms visible at mid-latitudes result from large flares on the Sun.

One way to keep abreast of solar activity and the possibility of auroral displays is through the National Oceanic and Atmospheric Administration's Space Environment Services Center in Boulder, Colorado. The center monitors and predicts solar activity as well as its probable effect on Earth. Detailed forecasts of activity are broadcast eighteen minutes past every hour on shortwave WWV. You can also phone the Boulder center for a taped forecast at (303) 497-3235 (which is a toll call). If you are planning a vacation to a dark-sky site and want a preliminary forecast of activity for the next 7-day and 27-day periods, write the Space Environment Services Center, NOAA, Boulder, CO 80303, and ask for the *Preliminary Report and Forecast of Solar and Geophysical Activity*.

Because auroral frequency and intensity are linked to solar activity, it is not surprising that they show the same 11-year cycle the Sun does. The peak in auroral activity, however, occurs a year or two after the peak in solar activity. Because the next solar maximum will occur in 1991, aurorae should be on the increase again. Despite this general pattern of activity, however, scientists still cannot predict just when an auroral display will take place.

The only way to make sure you will see an aurora is to keep a sharp eye on the sky. From most locations in the central and northern United States you should be able to spot at least one aurora this summer. And if you are traveling north and away from city lights this summer, your chances increase dramatically. (Though if you travel too far north the Sun brightens the sky all night during early summer.) Be observant — you never know when one of those rare and spectacular displays will happen.

Lights along the Zodiac

Although the aurora may be the most spectacular sky glow you can see in the night sky, there are other fascinating sky glows visible to the naked eye. The zodiacal light and its fainter cousins — the zodiacal band and the gegenschein or counterglow — are more elusive than the aurora and therefore more of a challenge to observe.

The zodiacal light is a beautiful and ethereal glow that is the easiest of the three to see. Visible shortly after evening twilight in the western sky and shortly before morning twilight in the eastern sky, the zodiacal light protrudes above the horizon in the shape of a huge parabola or cone and shines with a soft white light. Widest at the horizon and slowly tapering to a width of only 5° to 10°, the zodiacal light can reach halfway up the sky under the best conditions.

The brightest parts of the zodiacal light are slightly brighter than the Milky Way. This means that if you know where to look and what you're looking for, the zodiacal light is quite easy to see from a moderately dark site. However, as with faint aurorae, the zodiacal light is diffuse enough that haze or background light from nearby cities, street lights, or the Moon will mask the faint glow.

As its name implies, the zodiacal light is confined to the zodiac, the 18°-wide region of the sky centered on the ecliptic. The ecliptic is the plane in which Earth orbits the Sun and all the other planets lie close to the ecliptic. Thus, when the planets are visible, they can be used as a guide for locating the zodiacal light.

Many people who have seen the zodiacal light before might not have been aware of what they were seeing. Because of its diffuse nature, the light is often confused with twilight or the glow from a distant city. The best way to differentiate the zodiacal light from the others is by its shape — twilight and city glows appear relatively broad and flat and remain close to the horizon, while the zodiacal light is cone-shaped and follows the ecliptic.

The most significant factor governing the visibility of the zodiacal light is the angle the ecliptic makes with the horizon. When the ecliptic makes a small angle with the horizon, the zodiacal light remains low in the sky, where it is more difficult to distinguish from horizon glows. When the ecliptic makes a large angle to the horizon, the zodiacal light likewise makes a steep angle and is easier to see.

For this reason the zodiacal light is easiest to see from the tropics, where the ecliptic makes a steep angle relative to the horizon in the morning and evening at all times of year. In mid-latitudes there are definite "seasons" during which the zodiacal light is easier to see, and the seasons differ for morning and evening twilight.

In the evening sky in the Northern Hemisphere the ecliptic makes its steepest angle on the first day of spring (the vernal equinox) and its shallowest angle on the first day of autumn (the autumnal equinox). At a latitude of 40° the difference is substantial — 73.5° compared to 26.5°, respectively. At more southerly latitudes both angles are greater, and farther north both angles are smaller. The situation is exactly reversed in the morning sky: the best visibility for the zodiacal light is at the autumnal equinox and worst visibility at the vernal equinox.

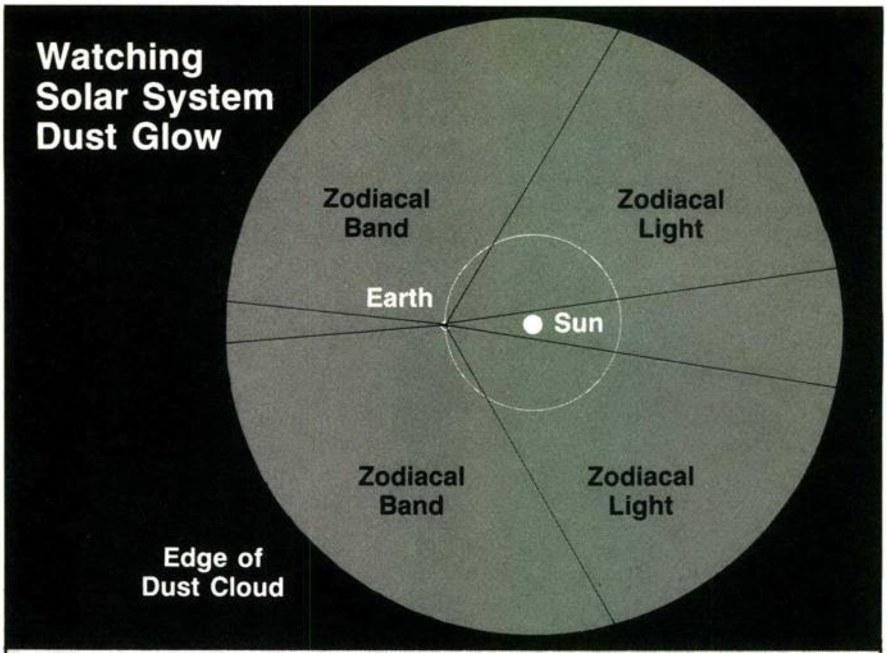
This summer your chances of seeing the zodiacal light in the morning sky before dawn will get progressively better, while your chances of seeing the zodiacal light in the evening sky after dusk will get progressively worse. If your vacation travels take you to a dark-sky site this summer, look for the zodiacal light in the evening early in the summer during the ten days before a New Moon. As July, August, and September roll around, your best bet for seeing the zodiacal light will be in the morning during the ten days following a New Moon.

Even more difficult to observe than the zodiacal light are the zodiacal band and the gegenschein. Very few people have ever seen these glows because they are so faint and diffuse. They are, in fact, the most difficult celestial sights visible to the naked eye. But under the best conditions both the zodiacal band and the gegenschein *are* visible to people willing to make the effort to see them.

The zodiacal band is an ill-defined extension to the zodiacal light that circles the entire zodiac. It shines with the same soft white glow as the zodiacal light, but the zodiacal band is fainter. The zodiacal band can be seen only under the darkest skies with no interference from haze, lights, or the Moon.

The gegenschein is a noticeably brighter component of the zodiacal band exactly opposite the Sun in the sky. It appears as a circular or slightly elliptical glow of diffuse light 18° in diameter. Under less than ideal circumstances its extent shrinks to 10° or less in diameter.

Because the gegenschein is so faint, you are more likely to see it when the antisolar point — the point opposite the Sun — is high in the sky, because then you are looking through less of Earth's atmosphere. This means the gegenschein is easiest to see around midnight and, for observers in the mid-latitudes of the Northern Hemisphere, during late fall or early winter. Even the slightest competing glow will hide the gegenschein, so try to observe it when the Moon is out of the sky and when that other diffuse glow, the Milky Way, lies as far away as possible. This latter condition is best met during the fall when the antisolar point tracks through the dim constellations of Aquarius and Pisces. (The antisolar point is also far from the Milky Way during late winter and spring, but the constellations of Leo and Virgo are much brighter and so tend to hide the gegenschein.) Your best bet for seeing the gegenschein is thus from late September until mid-November.



Microscopic bits of dust permeate the ecliptic plane in the inner solar system, and from Earth we can see sunlight reflecting off these particles. The reflection is brightest in the direction of the Sun where the dust is thickest, less bright directly opposite the Sun where the particles are fully illuminated, and faintest in between.

Dust in the Solar System

The zodiacal light, zodiacal band, and gegenschein are really three different manifestations of the same phenomenon — sunlight reflected off dust particles lying in the plane of the solar system. The subtle differences among the glows are due to the angles from which we view the reflected light.

The dust particles range in size from a fraction of a micron to several millimeters in diameter, although the majority are a few microns in diameter. The particles are the remains of previous meteor streams, which in turn originated in comets. The dust forms what is called the zodiacal cloud, which is confined to the ecliptic plane. The number of particles is greatest close to the Sun and falls off steadily out to the orbit of Mars. The cloud itself stretches from the Sun to near the orbit of Jupiter.

The structure of the zodiacal cloud determines the appearance of the zodiacal light, zodiacal band, and gegenschein. As we look toward the eastern horizon in the morning or the western horizon in the evening, we are looking in the general direction of the Sun. This is where the heaviest concentration of dust lies, so we see the brightest glow — the zodiacal light. Farther from the Sun the zodiacal cloud is less dense, so when we look farther from the Sun the zodiacal band appears fainter than the zodiacal light. The gegenschein is brighter than the zodiacal band because of our viewing angle. Even though there is less dust directly opposite the Sun, each dust particle we do see is fully illuminated. In effect, each particle is acting like a miniature Full Moon and reflects the maximum amount of sunlight possible toward Earth.

Many people will never see a spectacular auroral display, despite the statistical probability that at least one will be visible to virtually everyone during his or her lifetime. And most people will also go through life without ever seeing the zodiacal light — not to mention the zodiacal band or the gegenschein. Yet each is a beautiful sight that will amply reward a persistent observer. Make a point of getting away from the city lights and into the blackness of the countryside sometime soon. Any one of the naked-eye sky glows could repay your effort.

Philip M. Bagnall is director of the British Meteor Society's International Micrometeorite Research Network and lives in Wallsend, England. His last article was "The Quadrantids: Bright Prospects for 1987" in the January 1987 issue.

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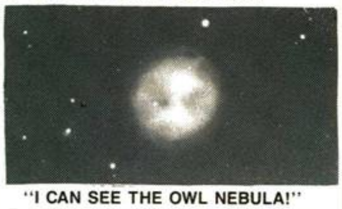

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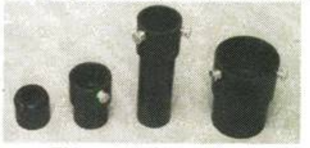

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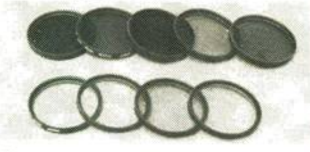

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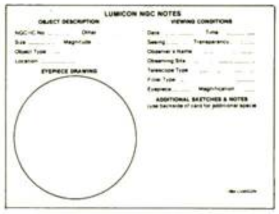
Yellow	480nm-IR	98%	**$18**
Green	490-590nm	60%	**$18**
Orange	560nm-IR	98%	**$18**
Red	600nm-IR	98%	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**
Cyan	340-580nm	95%	**$59**


LUMICON NGC NOTES
OBJECT DESCRIPTION
VIEWING CONDITIONS
EYEPIECE DRAWING
ADDITIONAL SKETCHES & NOTES

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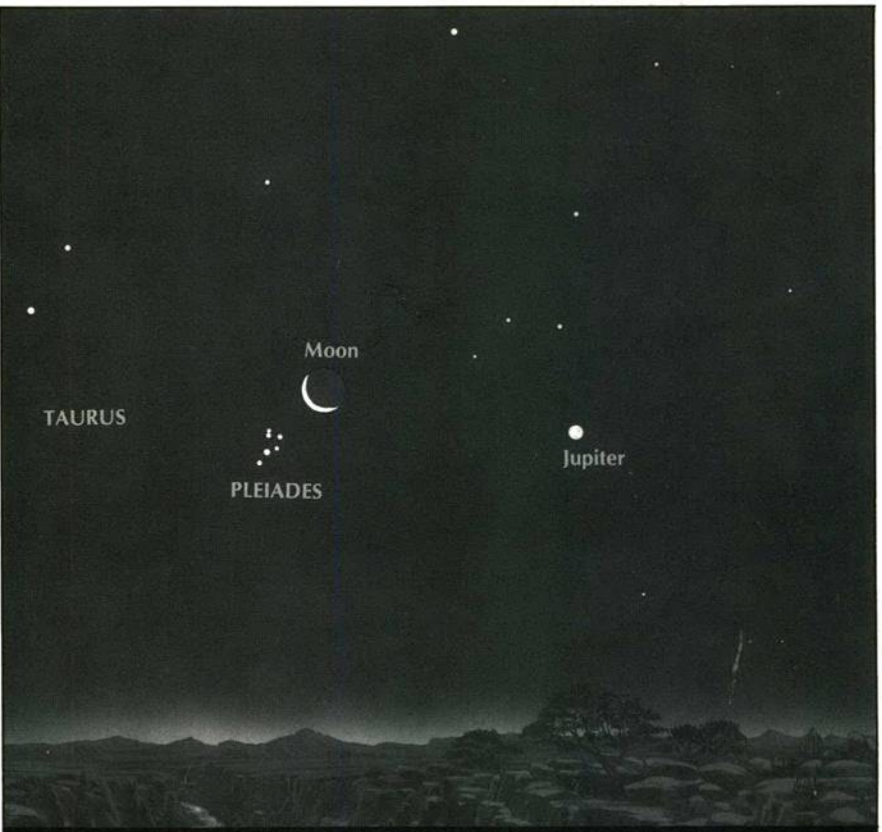
Saturn Overtakes Uranus — Again!

by Robert Burnham



Looking east-northeast, June 12, morning twilight

The Wanderers

When we left them last month in the evening twilight, Mercury and Venus were slipping quickly down to the western horizon. Both planets remain visible for the first two or three days of June but vanish into the Sun's glare thereafter.

To see one or both, you must find a place with an unobstructed western horizon — wide fields, a large lake, or even an ocean is ideal. Shining at −4.2 magnitude, **Venus** is the object to look for first. Having located it as the bright white "star" down in the yellowy twilight glow, look directly below Venus at about half Venus' elevation for **Mercury**, which shines at magnitude 2.4. It won't be easy to see: binoculars will help, but there's a fifty-fifty chance that Mercury will be lost in the twilight.

Both planets pass between Earth and the Sun, four hours apart, on June 13, and on the last few mornings of June they repeat their evening performance of June 1 — but in the eastern sky just before sunrise. Once again, bright Venus is the jump-off point and Mercury lies to Venus' lower left, half as high and one magnitude brighter than on June 1.

By the end of evening twilight, **Saturn** can be seen in the southeast. Though it lies in Sagittarius amidst the Milky Way's southern reaches, it is easy to pick out because it shines at zero magnitude. On June 20, Saturn is in opposition to the Sun, rising as the Sun sets and vice versa. One week later Saturn lies three Moon-diameters (1°21′) north of **Uranus**, a planet just visible to the naked eye.

The best way to locate Uranus is to look below Saturn *with binoculars*. (Uranus will appear like a magnitude 5.5 star; you'll need a telescope at about 100x to show Uranus' disk clearly.) If your sky is dark, try to spot Uranus with just your eyes. This "meeting" of Saturn and Uranus is the second of three encounters that occur this year. The first was on February 13, and the last is on October 18. However, these two planets will be near each other all year.

The predawn sky is home to two bright planets, Mars and Jupiter. As the growing twilight begins to reveal terrestrial objects around you, **Mars** is a ruddy object high in the southeast, shining prominently at magnitude −0.5. It stands out like a beacon in Aquarius, a region notoriously poor in bright stars. Eye-catching now, Mars will grow considerably brighter during the months to come as opposition (and closest approach) draw near.

At the beginning of June **Jupiter** is about as difficult to see as Venus is and low enough to require a really clear horizon. But by mid-month Jupiter is easily visible unless trees or houses press in closely on your viewing site. Lying among the stars of Aries and western Taurus, Jupiter is brighter (−2.0 magnitude) than any stellar objects near it. The Pleiades star cluster can be seen to Jupiter's left for a while each morning before it fades in the brightening twilight.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

The Starry Sky

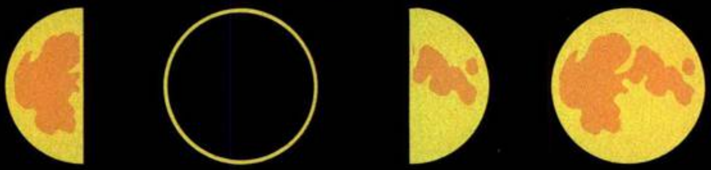
Though June often feels like summer, the stars of a June evening belong more to spring. Only the eastern sky contains the great star clouds of the Milky Way, which are the traditional hallmarks of summer stargazing. To appreciate the beauty of the nighttime sky, you should view from a location away from urban light pollution. You don't need to go far from home — even a little beyond the edge of the city will be a big improvement over your own backyard or the local park.

If you face north, you will see the familiar Big Dipper (alias **Ursa Major** the Great Bear) hanging from its handle to the left of Polaris, the pole star. Begin with the bright Dipper and try to identify the rest of the Bear. After that, trace the figure of **Ursa Minor** the Lesser Bear standing on its tail.

To the right of Polaris, the elongated "home plate" of **Cepheus** the King lies next to the Milky Way. And above him is the head of **Draco** the Dragon. Draco's tail snakes between the two Bears, and the Dipper's handle forms an arc pointing upward to Arcturus, an orange star in **Bootes** the Herdsman. Tall and kitelike, Bootes resembles a wide necktie or an ice cream cone with feet.

Opposite page: A bright summer meteor flashes by the cup of the Big Dipper in a star-filled Canadian sky. Photo by Dennis Leatart, taken last July with a 28mm lens at f/2.8, Ektachrome 400 film, and a 10-minute exposure.

June Night Sky



Last Quarter	New Moon	First Quarter	Full Moon
June 7	June 14	June 22	June 29
2:21 a.m. EDT	5:14 a.m. EDT	6:23 a.m. EDT	2:46 p.m. EDT

1st The Moon, one day past Full, lies 6° south of Saturn in the evening sky.

4th The Moon is closest to Earth at 7:45 p.m. EDT: 228,965 miles (368,484 kilometers).

7th Last Quarter Moon occurs at 2:21 a.m. EDT in Aquarius.

12th Two days before New, the Moon lies 6° north of Jupiter in the morning twilight (see diagram on page 54). For viewers in western North America the Moon passes through the Pleiades star cluster late in morning twilight, just before sunrise.

13th Venus and then Mercury pass between Earth and the Sun (inferior conjunction). You'll be able to see them both very low in the northeast before sunrise on the last few mornings of June.

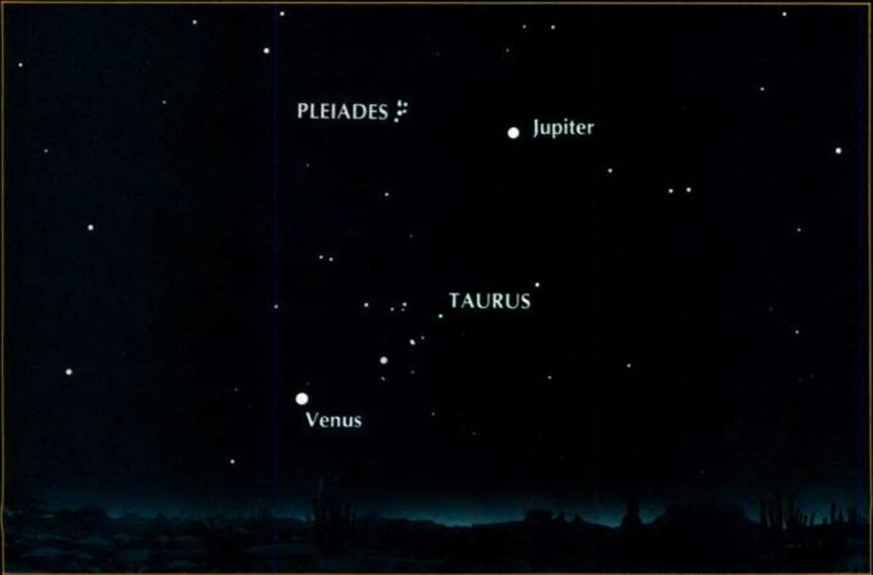
14th The Moon is New at 5:14 a.m. EDT in Taurus.

20th The Moon is farthest from Earth at 4:12 a.m. EDT: 251,371 miles (404,542 kilometers). Uranus, at magnitude 5.5, is at opposition to the Sun, which is the best time to look for this (barely) naked-eye planet (see text for details). Five hours after Uranus, 0.0-magnitude Saturn is also at opposition. The solstice occurs at 11:57 p.m. EDT and summer officially begins in the Northern Hemisphere.

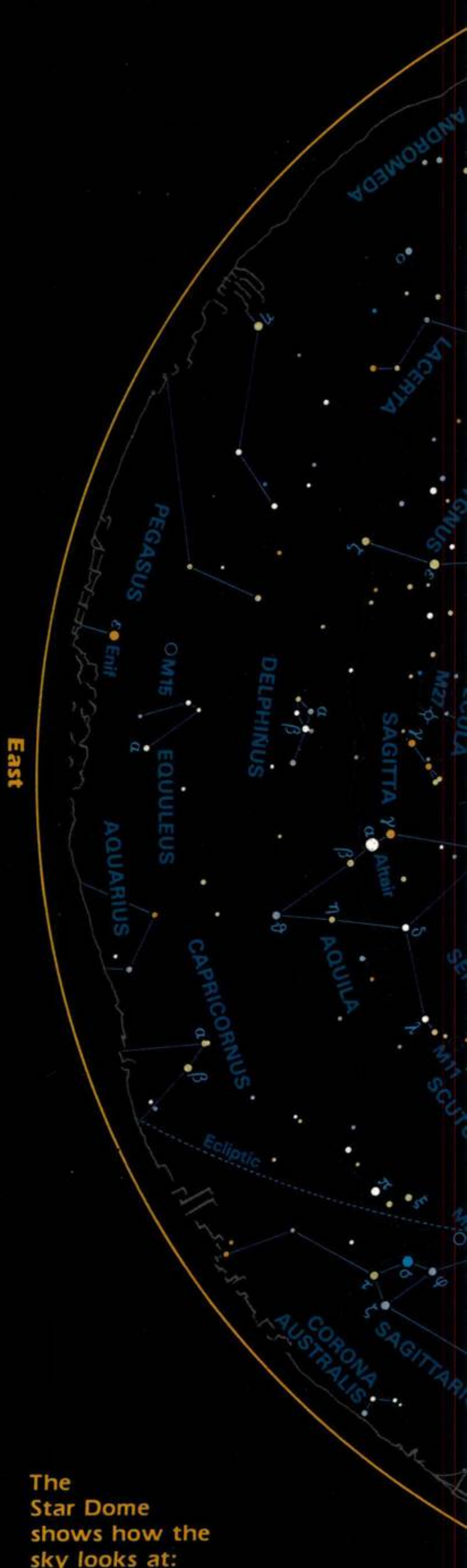
22nd First Quarter Moon is at 6:23 a.m. EDT in Virgo.

29th Full Moon (sometimes called the Rose or Flower Moon) occurs at 2:46 p.m. EDT in Sagittarius.

30th Neptune is at opposition at magnitude 7.9. Venus joins Jupiter in the predawn sky (see diagram below).

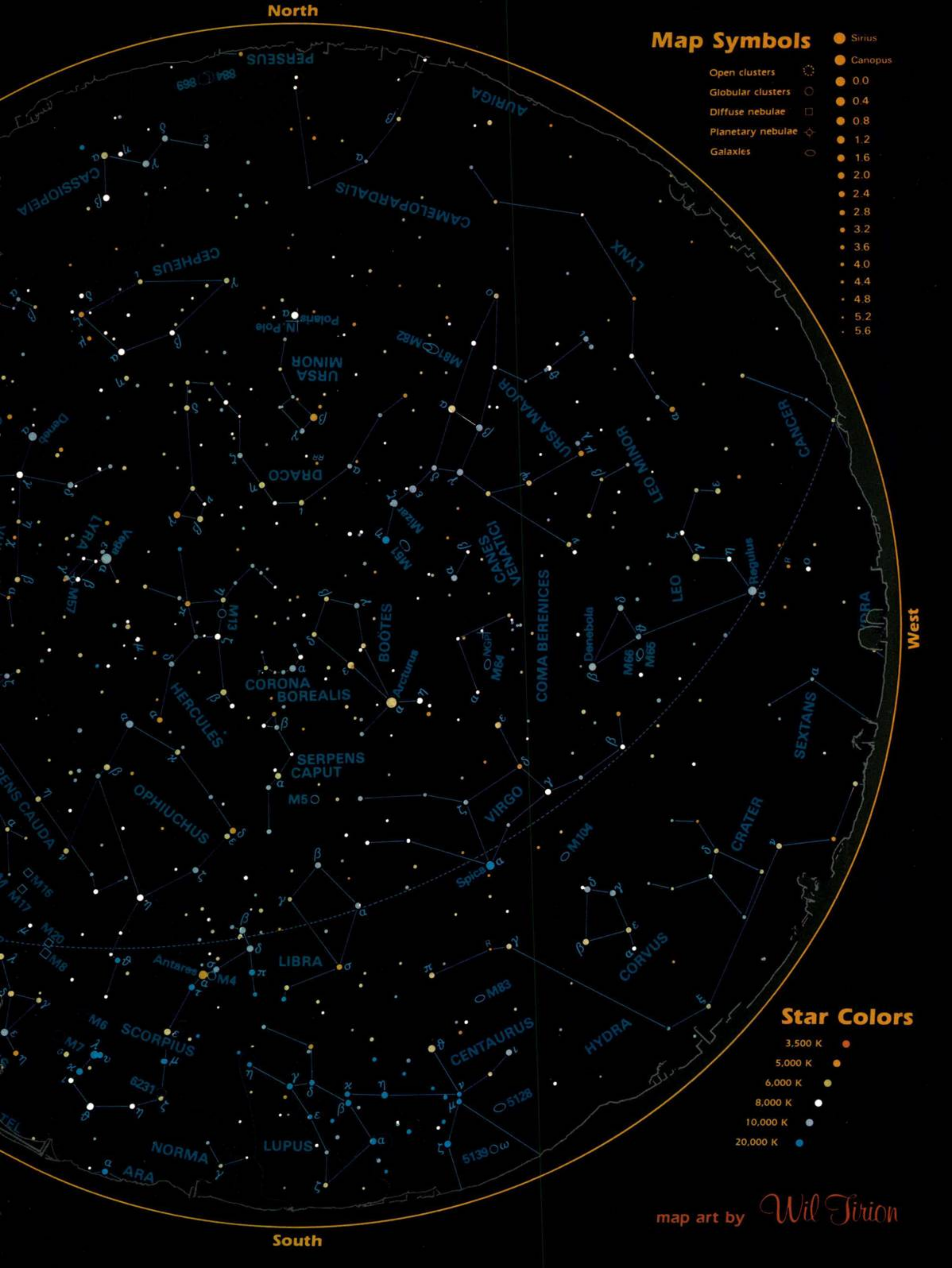

PLEIADES
Jupiter
TAURUS
Venus

Looking east-northeast, June 30, morning twilight


East
ANDROMEDA
LACERTA
PEGASUS
Enif
M15
DELPHINUS
EQUULEUS
SAGITTA
M27
Altair
AQUILA
AQUARIUS
CAPRICORNUS
Ecliptic
M11
CORONA AUSTRALIS

The Star Dome shows how the sky looks at:

Midnight on June 1
11 p.m. on June 15
10 p.m. on June 30


North
Map Symbols
Sirius
Canopus
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
PERSEUS
884
869
AURIGA
CASSIOPEIA
CAMELOPARDALIS
CEPHEUS
LYNX
Polaris
N. Pole
M81
M82
URSA MINOR
URSA MAJOR
LEO MINOR
CANCER
Deneb
DRACO
Mizar
M51
CANES VENATICI
COMA BERENICES
LYRA
Vega
M57
M13
BOÖTES
NGP
M64
Denebola
M66
M65
LEO
Regulus
HYDRA
West
CORONA BOREALIS
Arcturus
HERCULES
SERPENS CAPUT
M5
SERPENS CAUDA
OPHIUCHUS
VIRGO
SEXTANS
M104
CRATER
Spica
M16
M17
M20
M8
LIBRA
CORVUS
Antares
M4
M83
SCORPIUS
M6
M7
6231
CENTAURUS
HYDRA
5128
LUPUS
5139
NORMA
ARA
South
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K

map art by Wil Tirion

If you face west, the two stars at the end of the Dipper's bowl point down and left toward a bright star in **Leo** the Lion called Regulus. Leo is balancing on its forepaw (Regulus), while its head and mane form a backward "?" called the Sickle. Leo's hindquarters — a right triangle — end in Denebola.

Above Denebola a faint gathering of stars glows gently — this is **Coma Berenices**, Berenice's Hair. To its left the bright blue-white star Spica marks an ear of wheat held in the hand of **Virgo** the Maiden (see Skylore).

High overhead, the small semicircle of **Corona Borealis** nestles between Bootes and **Hercules**. Upside down, Hercules' body is a keystone from which its legs run north and its arms south. (M13 in the keystone is a globular cluster that looks like a fuzzy star in binoculars.) Below Hercules' head the Serpent-Bearer **Ophiuchus** stands with its feet touching the ecliptic (or zodiac), the path the Sun follows during the year. The Serpent itself is divided in two: the head (**Serpens Caput**) lies next to Bootes and the tail (**Serpens Cauda**) reaches into the Milky Way.

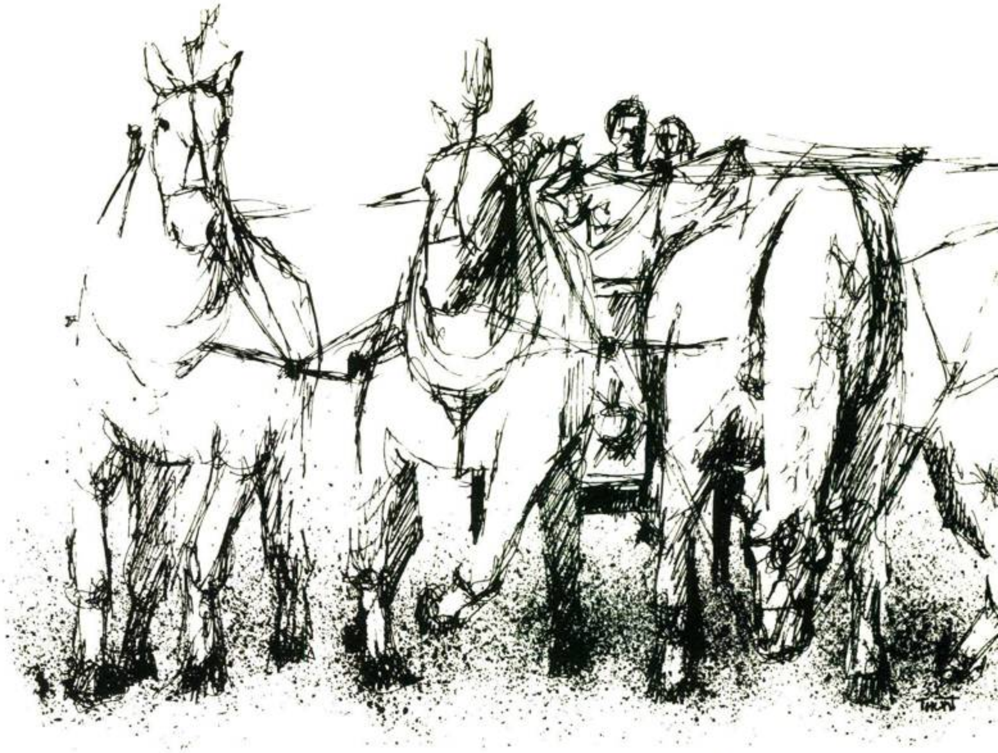
Below, the Scorpion **Scorpius** curls its stinger as if to stab Ophiuchus in the foot. The region around 1st-magnitude Antares is beautiful when explored with binoculars. To the lower right of Scorpius we are seeing the northern reaches of the Centaur (**Centaurus**) and the Wolf (**Lupus**). Behind Scorpius, the Archer **Sagittarius** (including bright Saturn) is rising into view, along with the center of the Galaxy. This region offers an unparalleled sweeping-ground rich in clusters, nebulae, and star clouds for binoculars and small telescopes.

North along the Milky Way we pass **Scutum** the Shield to meet diamond-shaped **Aquila** the Eagle. Its brightest star is white Altair. Next come tiny **Sagitta** the Arrow and the less distinct Fox **Vulpecula**. Finally **Cygnus** the Swan, with bright Deneb in its pinfeathers, spreads its wings to span the Milky Way. Above Cygnus lies the diminutive geometry of **Lyra** the Lyre with its jewel, zero-magnitude Vega. Taken together, Altair, Deneb, and Vega form the Summer Triangle, an asterism that will be part of the night sky from now until late autumn, when the onset of winter carries them out of view.

Skylore

In Virgo the Maiden we meet one of the great archetypes of folklore. This ancient figure probably originated eight or nine thousand years ago, when an astronomically naive mankind, just beginning to get involved with agriculture, struggled to comprehend the climatic vagaries of a baffling world that handed out life or death randomly.

Opposite page: Look for Venus very low in the eastern morning sky at the end of the month. This is how Venus appeared in March 1987 before dawn over the Caribbean Sea. Photo by Jeff Kanipe, taken with a 50mm lens at f/2.8, Ektachrome 64 film, and a 1-second exposure.



In Babylonian myth, Virgo was the great goddess of fertility, Ishtar. Her husband was Tammuz, slain one day by a boar — actually Winter in disguise. When Ishtar went down to the underworld to look for Tammuz, Winter seized the opportunity to cover the lands of men with deadly cold. Crops and cattle died; people grew afraid.

Ishtar found Tammuz and, through a stratagem, got him released and restored to life. When Ishtar and Tammuz returned to the upper world, Winter's reign ended. A joyous spring began as green life spread across the land. But death's defeat is never final, and each year the drama is reenacted.

To the Greeks, Virgo was Demeter. She was the sister of Zeus, who fathered Demeter's daughter Persephone. One day Persephone was gathering flowers when Hades, god of the underworld, drove past in his chariot pulled by four night-black horses. Hades lured her aboard and drove off. Striking the ground with his trident, he opened the earth and returned to his dark kingdom to make Persephone his queen.

Demeter, who knew only that her daughter had suddenly vanished, became angry and decreed that nothing would grow again until Persephone returned. All over the world, crops failed and no seed germinated. Mankind faced the worst famine in its history.

When she learned of Hades' theft, Demeter pleaded with Zeus to let Persephone come back. Zeus claimed Hades was not unworthy, but Demeter refused to listen. Zeus then allowed Persephone to return, provided she had eaten nothing while in the underworld. Unfortunately, at Hades' urging, Persephone had nibbled six pomegranate seeds. Yet faced with an unyielding Demeter and the ruin she was inflicting on Earth, Zeus finally ruled that Persephone could spend half the year with her mother if she spent the other half with Hades.

Thus it is that during the six months when Persephone is in the world of men, Demeter is happy and crops flourish. But in the other half of the year a saddened Demeter lets winter rule the world unchecked. (When the Romans adopted the story, they changed only the names: Demeter became Ceres, Persephone became Proserpina, Hades became Pluto, and so on.)

The traditional picture of Virgo shows a winged woman holding an ear of wheat in her left hand (the star Spica) and sometimes an olive branch in her right. The wheatear identifies her as Demeter, but the olive branch symbolizes a different tradition, in which Virgo is Astraea, goddess of peace and justice.

Long ago, so the story goes, the world experienced several ages. First came the Age of Gold, a strifeless time in which Astraea met with men and women to frame fair laws for them. In the Silver Age that followed, her force was weaker and people paid her less heed, even as she rebuked their occasional wickednesses.

Finally came the Ages of Bronze and Iron. In these desolate times, which extend to our own day, Astraea came to loathe what the generations of men had become. Her patience gone, she left — the last of the deities to depart from Earth. Now, from a safe place in the zodiac, she weighs the deeds of mankind on the scales of neighboring Libra.

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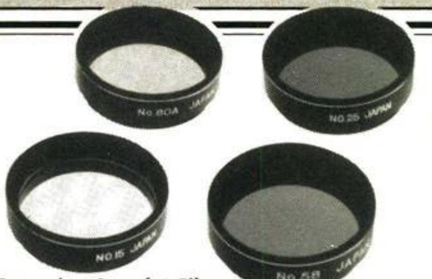

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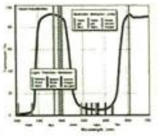

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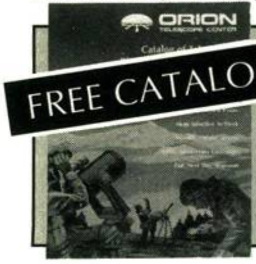

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Reader Reports

Searching for Supernovae

A potpourri of astronomical subjects caught the eyes and lenses of many observers last fall and winter — everything from extragalactic supernovae to spectacular solar haloes. Readers have also been avidly watching Jupiter, which has proved very active this apparition, displaying festoons, dark spots, and "bridges."

The Discovery of Supernova 1987L

Perhaps it was the attention garnered by supernova 1987A in the Large Magellanic Cloud, or maybe it was the yearnings of deep-sky observers to *do something* with their telescopes rather than passively observe through them. Whatever the cause, the search for supernovae in galaxies has become a popular pursuit for a sect of observers with dark skies and a lot of persistence and dedication. A typical success story (if you can label any of these stories "typical") is Dana Patchick's discovery of supernova 1987L.

Although supernova 1987L was discovered in August 1987, we thought the story of its discovery might be inspiring to observers who have been looking long and hard for new stars in the disks of distant galaxies.

The supernova was detected in NGC 2336, a 10.5-magnitude multiarm spiral in Camelopardalis. The supernova was initially detected by Patchick, a Los Angeles amateur astronomer and supernova searcher, on the morning of July 27. However, the new star and the brightening dawn sky worked against him. The supernova was bright enough to throw off the charted star patterns around the galaxy's nucleus, so Patchick believed that at first he did not have the correct galaxy field. By the time he had referred to his charts and double-checked the field stars, the brightening dawn sky had overwhelmed the stars in the field of view, preventing him from determining whether the supernova was there or not.

"The very best I could admit to myself," said Patchick, "was that I thought I had seen something out of place that could possibly have been a supernova. But I told myself that it probably was not."

It would be three weeks before Patchick would get the chance to study NGC 2336 again. Patchick asked a fellow observer, Kevin Hook, to accompany him to their favorite observing site in the Santa Monica Mountains. Patchick and Hook assembled their 17.5-inch telescope and began looking for supernovae in Virgo and Canes Venatici, regions rich in galaxies.

"Although I intended to check up on the possible sighting in NGC 2336," said Patchick, "I put it off because I wanted the galaxy to rise to a better position."

At about 12:45 a.m. the galaxy had risen so Patchick could comfortably study it in the eyepiece.

"For a long time I went back and forth, checking the eyepiece field and then the search chart, and encountered the same confusion with the star patterns. I cursed the chart and then the chartmakers. Instead of realizing that there was a new star, I kept believing I wasn't interpreting the chart correctly.

"I continued to trace the bright, easy star patterns first and then worked on the fainter ones. Slowly it began to sink in. All the patterns fit perfectly when I weeded out the one intruder. I had been examining the field for probably fifteen minutes when I quietly told Kevin: 'I think I've got a supernova.'"

The supernova was subsequently confirmed by veteran supernovae searcher James Bryan of Georgetown, Texas, and designated 1987L by the International Astronomical Union. After some confusion in interpreting spectra of the new star, astronomers classified the supernova as Type Ia about a month past its maximum brightness. The supernova's magnitude was about 14.5 in late August 1987, but by early September it dropped below 15.

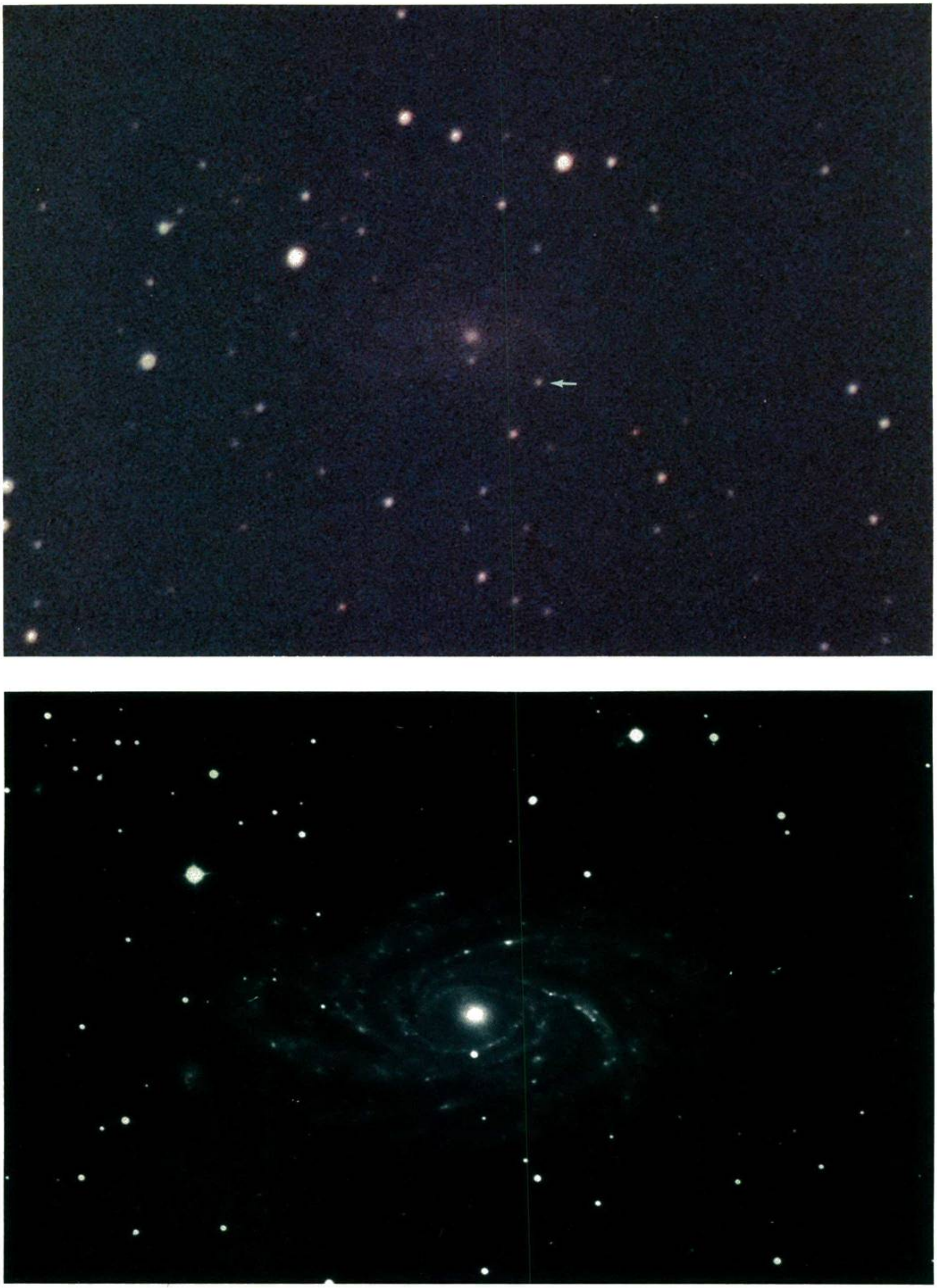
Jupiter Reports

The 1987/88 apparition of Jupiter has been touted by many observers as the best in twelve years. At opposition on October 18, 1987, Jupiter's disk was nearly 50" across, and telescopes of all sizes were able to show disk detail that isn't visible when the planet is located farther from Earth. But even during the months prior to and after opposition the planet was large enough so observers with small telescopes could study subtle cloud features.

New York State observer Frank Mellilo noted unusual atmospheric activity in Jupiter's northern hemisphere, as well as interesting features appearing in the North Polar Region, the North Temperate Belt, and the North Equatorial Belt. Mellilo, who made his observations with an 8-inch SCT, reported that the most famous feature on the planet, the Great Red Spot, remained pale throughout the apparition and exhibited only a slight blush of pink. Jose Olivarez, the Jupiter recorder for the Association of Lunar and Planetary Observers, described the Red Spot as "ringlike with a light interior." It was most noticeable where the "bay" or "hollow," the oval region in which the Red Spot is located, notched the darker South Equatorial Belt.

Among the notable features Mellilo reported observing between mid-August and mid-December were a rift in the South Equatorial Belt that extended nearly around the globe (August 17, 1987); a blue spot in the North Equatorial Belt (October 2, 1987); a dark rod between the North-North Temperate Belt and the North Temperate Belt, as well as two blue spots in the southern region of the North Equatorial Belt; a dark patch in the North Polar Region (November 23, 1987); and blue spots seen in the southern region of the North Equatorial Belt (December 7, 13, and 19, 1987).

Meanwhile, Australian observer Zdravko Novak used two reflectors — a 6-inch f/5.5 and a homebuilt 8-inch f/9 — and a 9-inch f/15 refractor to study the Jovian disk last autumn. One of his most



Jack Newton's photo (top), taken August 26, 1987, shows supernova 1987L at magnitude 14.5 along the inner part of one of NGC 2336's spiral arms. The star directly adjacent to the nucleus is a foreground star. The supernova was discovered by Dana Patchik in the multiarm spiral galaxy NGC 2336, shown in a U.S. Naval Observatory photograph (bottom).

intriguing observations occurred on November 15, 1987, when he detected a bridgelike structure stretching across the western end of the Great Red Spot, which gave the famous feature the appearance of a "teardrop at the corner of an eye."

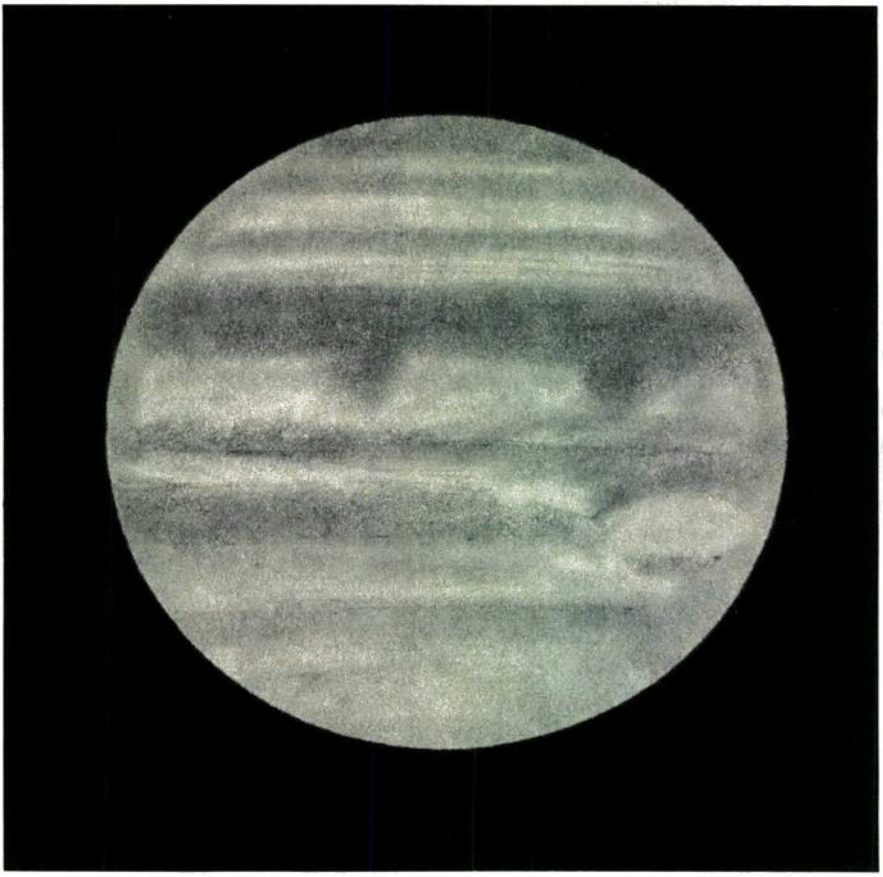
Conjunctions, Comets, Craters, and Haloes

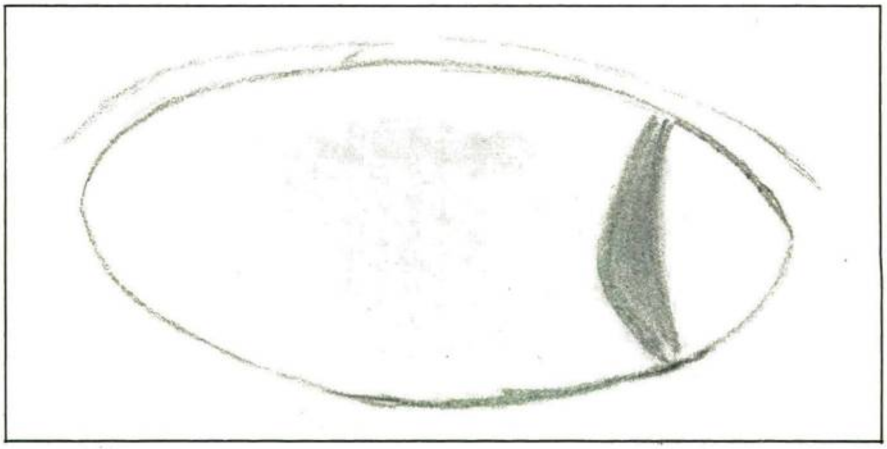
Many astrophotographers were attracted to last February's conjunction of Mars, Saturn, and Uranus, which could be seen in the constellation Sagittarius just before dawn. (Saturn and Uranus will linger in the same region of sky for the next five months. Mars, however, is now well to the east in Aquarius.) John Asztalos of Waukesha, Wisconsin, was well placed on the morning of February 23 at Haleakala National Park in Hawaii, 10,000 feet above sea level, to see the conjunction in a dazzling star-filled sky.

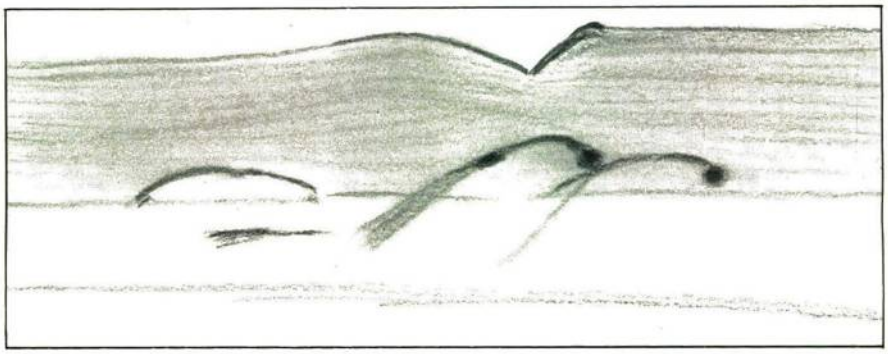
"Mars and Saturn were only a few hours past conjunction," said Asztalos. "But they were so bright and so close to M8 and M20 that the two nebulae were difficult to see in the binoculars."

On the comet front, things have quieted down a little now that Comet Bradfield is receding toward the outer solar system. Another comet that peaked this winter, Comet Borrelly, was worth at least a look if not a photograph, though it was no Comet Bradfield. California observer and astrophotographer Chris Schur obliged us with his photo of the 7th-magnitude comet taken January 9, as the comet was on its way out of the solar system. During mid-February and early March the comet's magnitude dropped to below 10th magnitude and was fading fast. By now, Comet Borrelly, like Bradfield, is just a memory.

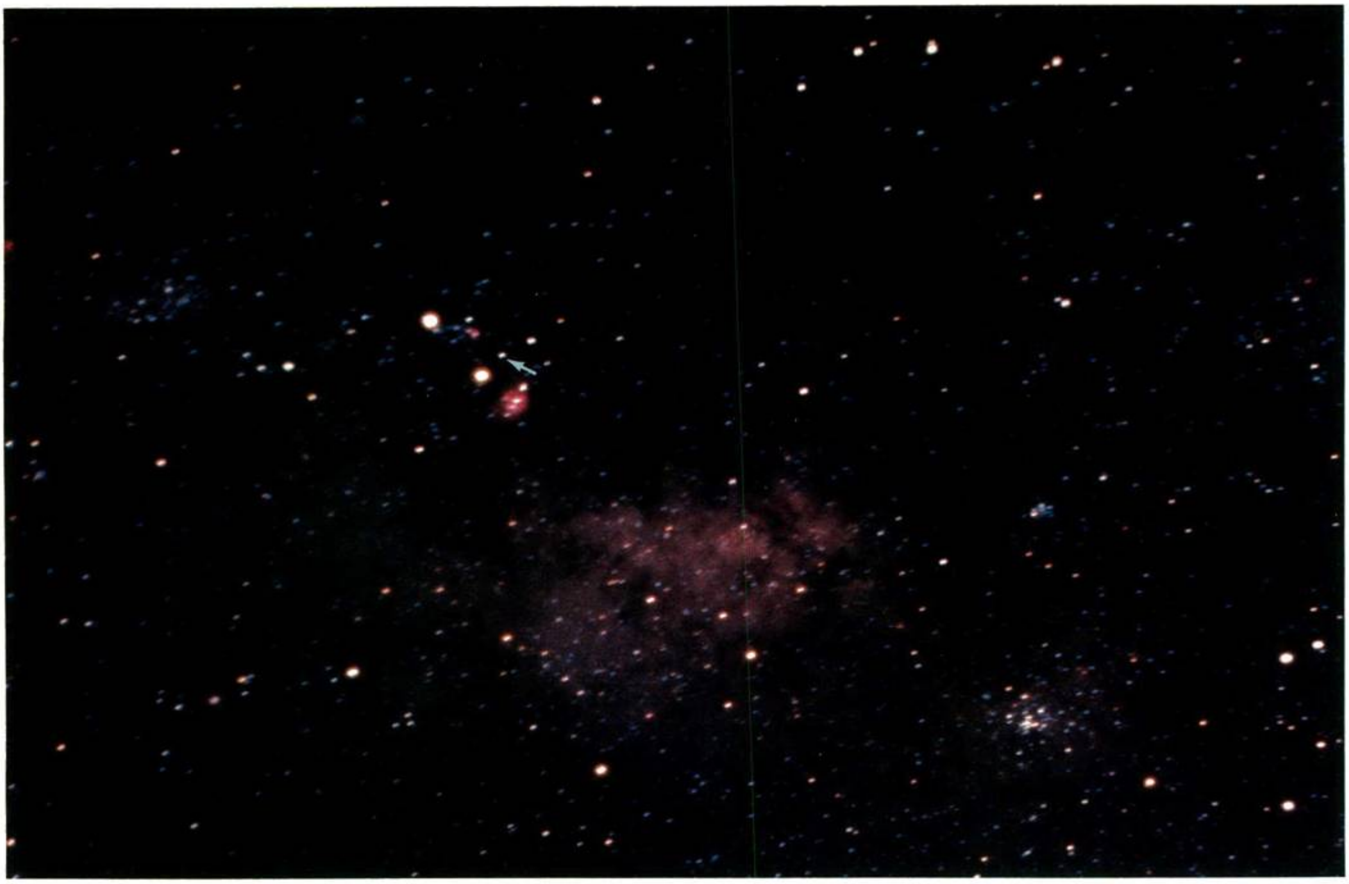
Have you explored the Moon lately? Many observers find studying the rugged lunar surface for rilles, peaks, and craters and then sketching these features both fascinating and challenging. Like deep-sky observing, the more you observe, the







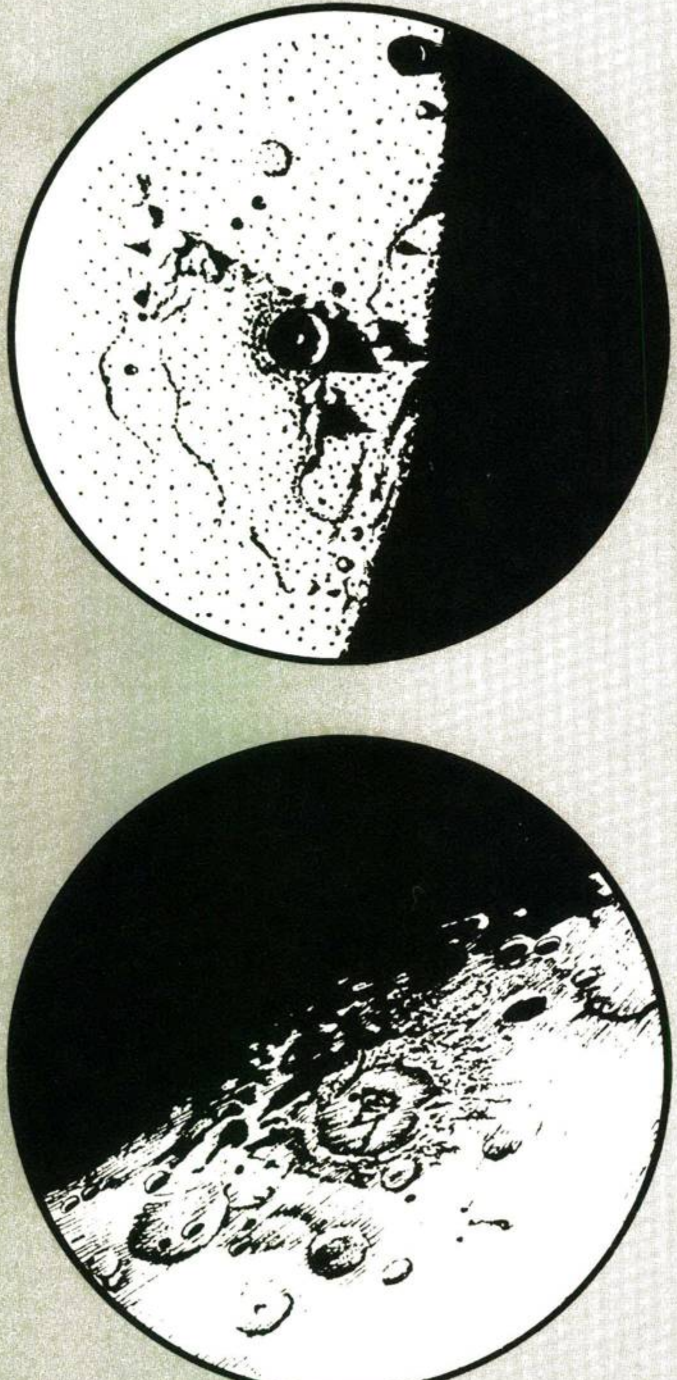
During its 1987/88 apparition Jupiter lived up to observers' expectations as a planet with ever-changing cloud features. Frank Melillo's sketch (top) made November 23, shows the Red Spot Hollow at the lower right limb, two blue spots protruding from the south edge of the North Equatorial Belt, and a dark patch in the North Polar Region. Eight days earlier Zdravko Novak sketched a thin, dark lane crossing the Red Spot (middle). And just two months before opposition, on August 19, 1987, Novak sketched blue spots and their associated festoons encroaching on the Equatorial Zone (bottom).



Mars, Saturn, and Uranus (arrow) as they appeared in the Sagittarius star clouds the morning of February 23, 1988, from Haleakala National Park, Hawaii. Saturn is the uppermost of the two bright "stars" to the upper left of the reddish Lagoon Nebula. Photo by John Asztalos, taken with a 50mm lens at f/2, Ektachrome 400 film, and a 10-minute exposure.

Comet Borrelly displayed a bright nucleus and a broad dust fan on January 9, 1988. Photo by Chris Schur, taken with a 16-inch f/4.5 Newtonian, Konica 400 film, and a 15-minute exposure.

Opposite page: From a ship off the coast of Brazil, John Maynard captured a 360° halo and a partial secondary halo ringing the Sun on January 16, 1988. Maynard used Kodak Vericolor Professional film, a polarizing filter, a 28mm lens at f/8, and a 1/500-second exposure.



Lunar craters were the target of Howard Moore III's 8-inch SCT last fall. The tall peak at the center of the crater Eratosthenes caught the sunlight rising across the Apennine Mountains (top sketch) one day after First Quarter. The Sun was at just the right angle to reveal the cracked floor of the crater Petavius two days after Full Moon (above). Moore used 220 power for both sketches.

more you see. And sketching helps direct the eye to see more detail.

After observing the Moon for a year, South Carolina observer Howard Moore III thought he'd try his hand at sketching the lunar surface with an 8-inch SCT and a magnification of about 200x. In one sketch Moore detailed the prominent rille in crater Petavius, located near the Moon's southeastern limb. The rille runs across the floor from the massive peak to the crater's terraced walls.

Among all the reader reports we received this month, John Maynard's was the most beautiful. On January 16, 1988, Maynard was aboard the cruise ship M/S *Sagafjord*, twenty miles off the coast of Brazil. Overhead the sky was clear except for some high, thin cirrus clouds. Around noon Maynard noticed a brilliant halo encircling the Sun with a radius of 22 °, as well as a partial secondary halo located farther out. Using a smokestack to block the Sun, Maynard snapped several shots of the haloes, two of which appear on page 66.

Such haloes are caused by ice crystals in the cirrus clouds refracting sunlight. A concentration of rays emerging from the crystals at the particular angle of 22 ° from the Sun forms the rainbow.

With summer well on its way, it's time to take your scopes and binoculars outside to look at the sky. Mars is already a prominent object in the morning sky, well up in the south four hours before dawn. Saturn comes to opposition later this month. With its rings tilted over 26° toward Earth, it should make an interesting study in the telescope. And don't overlook Saturn's near pass of Uranus — just 1.3° north of the blue-green, 5.5-magnitude planet — on June 27. With the pair of planets set against the backdrop of star clusters and bright nebulae in Sagittarius, this event should be worth a look through binoculars and perhaps even a photograph.

— *Jeff Kanipe*

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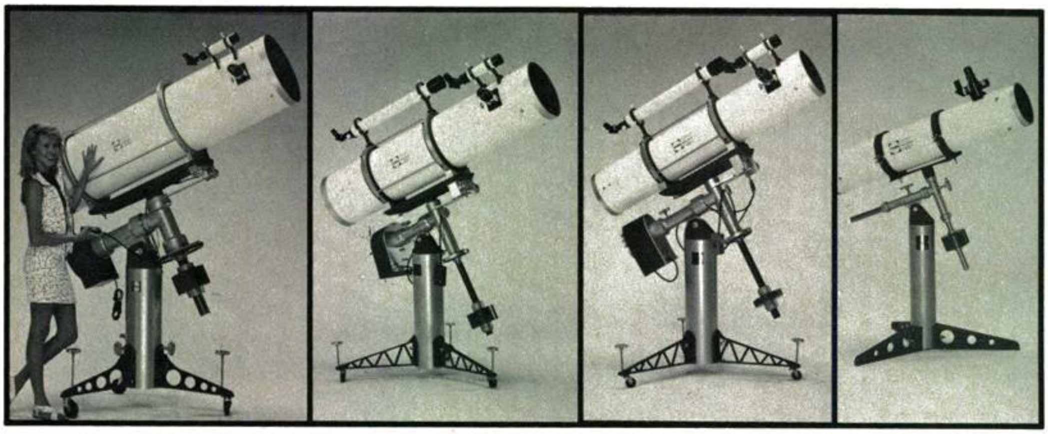

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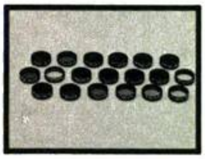

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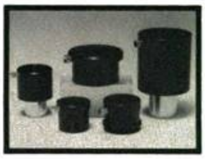

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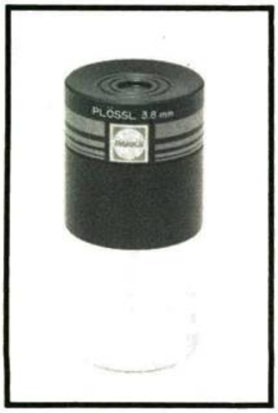

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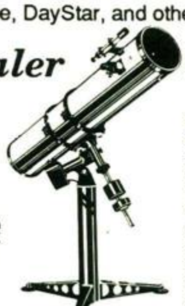

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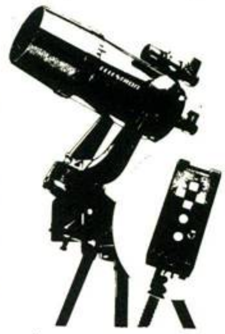

An open letter to our competitors –

We hear that some of you have been complaining about our low price on this magnificent telescope. Sorry, guys, but our customers deserve big savings more than you deserve a fat profit. For one more month, we're giving our customers Celestron's newest Powerstar ***II*** 8" Schmidt-Cassegrain for only $1599! These are not the older and discontinued Powerstar 8 telescopes some of you dealers are offering. These are Celestron's very latest Powerstar ***II*** models. Our customers get all these features and accessories: Starbright coated optics; 8 x 50mm illuminated polar axis finderscope; 1.25" 26mm Plossl eyepiece (77x); 1.25" 7mm orthoscopic eyepiece (286x); quartz-controlled Byers worm gear drive with power adapters for both AC and penlight battery operation; hand control with built-in map light, controls for optional electric focuser, and dual-axis drive corrector operation; equatorial wedge; adjustable height tripod; deluxe heavy-duty Samsonite-type molded foam-lined carrying case; lifetime warranty; and even more! ***$3000 list, for only $1599!*** *Our customers save 47%!* (The *new-style snap-on* optional $160^{00} dec motor that converts the Powerstar ***II*** drive into a dual axis drive corrector for astrophotography is only $112^{50}, while the *new-style snap-on* optional $150^{00} Powerstar ***II*** electric focuser is only $104^{50}. The optional Dewstar dewcap shown in the illustration is $24^{00}.)

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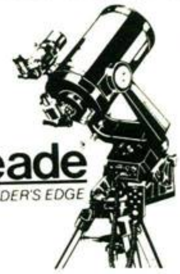

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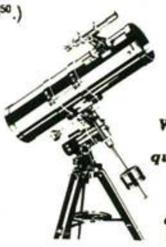

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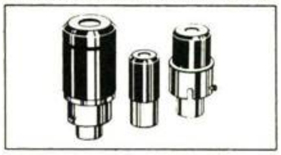

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Conquering the Cepheus Nebula

Photography in Astronomy

by Mace Hooley

The Cepheus Nebula, IC 1396, had always frightened the hell out of me. Sure, I'd taken plenty of pictures of bright deep-sky objects before, like the Lagoon Nebula, the Orion Nebula, and the Trifid Nebula. But who was I to photograph an object so well known for eluding the most experienced deep-sky observers?

On July 12, 1985, I confronted my fear of faint nebulae and worked up the courage to photograph the Cepheus Nebula. I was determined not to come away empty-handed. After careful planning, I transported my 8-inch Schmidt camera to a site 8,500 feet up in the San Francisco Mountains in northern Arizona. I loaded the camera with fast color film. The sky was dark, Cepheus was near the zenith, and my pack was stuffed with boxes of No-Doz.

What exactly is the Cepheus Nebula? IC 1396 is a large cloud of glowing hydrogen gas similar in nature to the Lagoon and Rosette nebulae. These so-called HII regions contain gas molecules ionized into glowing like a fluorescent light by nearby hot stars. Why then is IC 1396 so much fainter than other nebulae? There are few young, hot stars near IC 1396 to excite the nebula's hydrogen gas into glowing as the stars embedded in brighter nebulae do.

The 4th-magnitude star Mu Cephei, visible to the naked eye as a ruddy orange point of light, lies along the same line of sight as IC 1396 but is not associated with the nebula. I easily found Mu Cephei and then lined up my Schmidt camera on the star. The surrounding field covered by the Schmidt would also contain the Cepheus Nebula. Because the object is so faint, my strategy was to produce several negatives and then sandwich them together to make a slide duplicate. This would increase the contrast and allow me to enrich the color in the final slide. If I were shooting the Rosette or the California Nebula, for example, I might have taken a single 20-minute exposure. But the Cepheus Nebula required three

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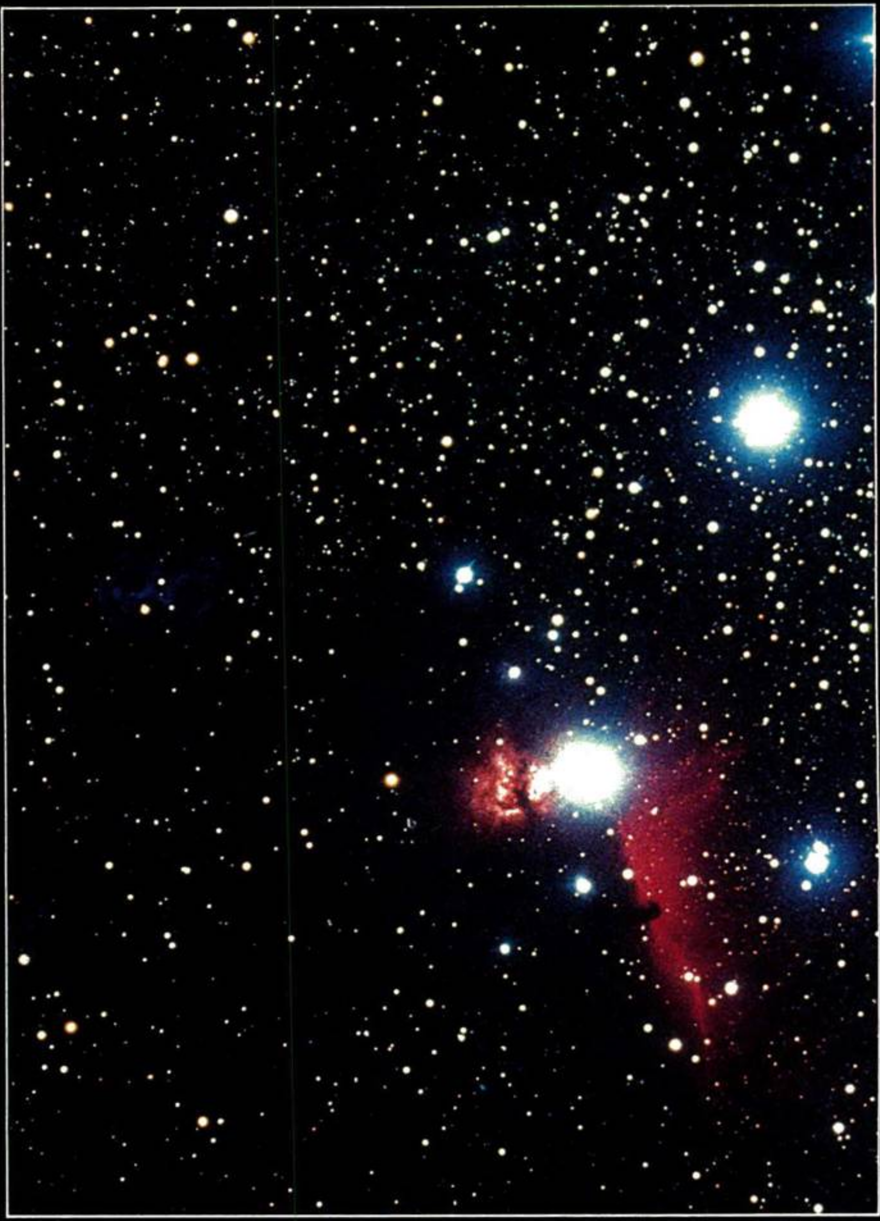
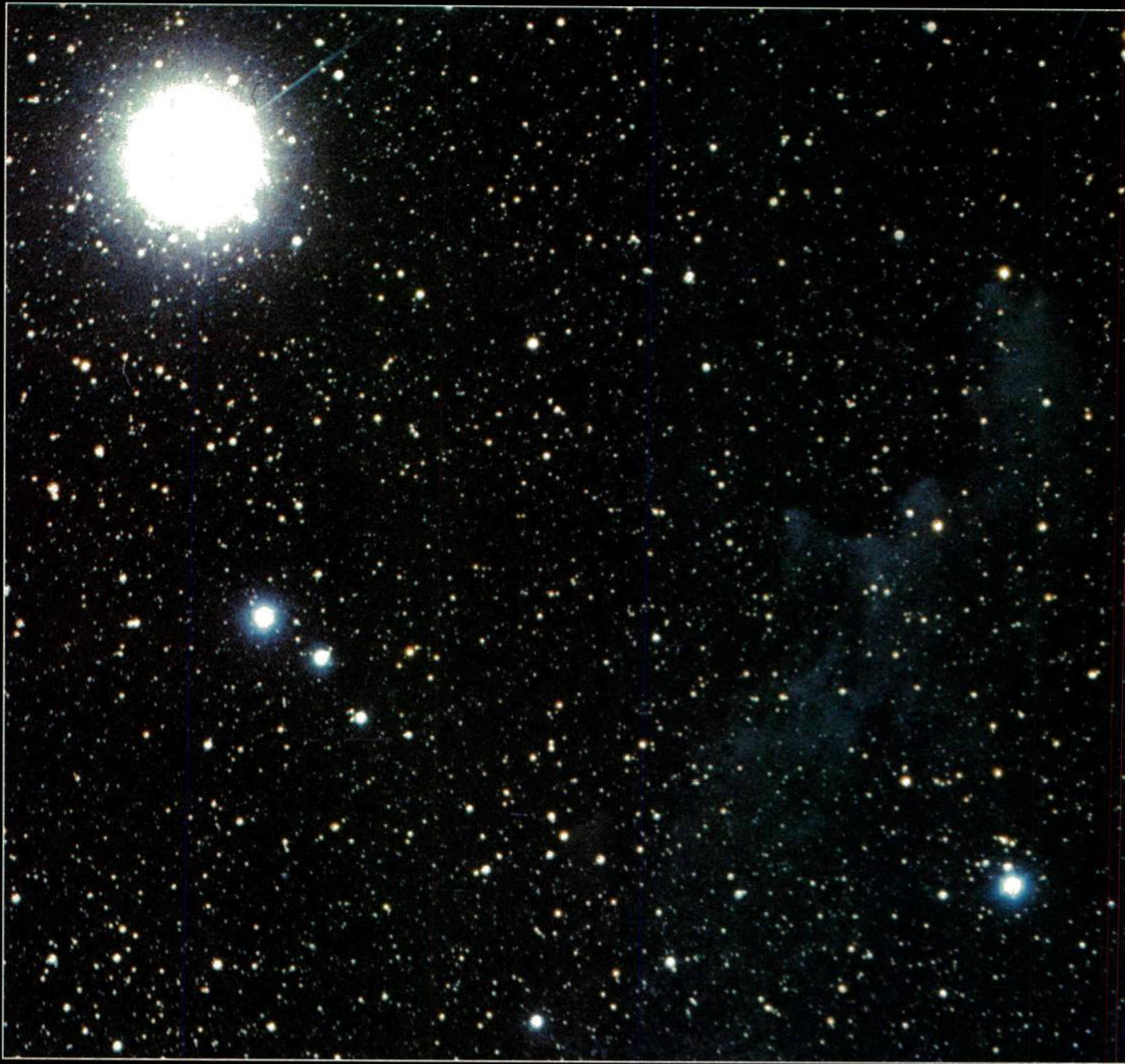
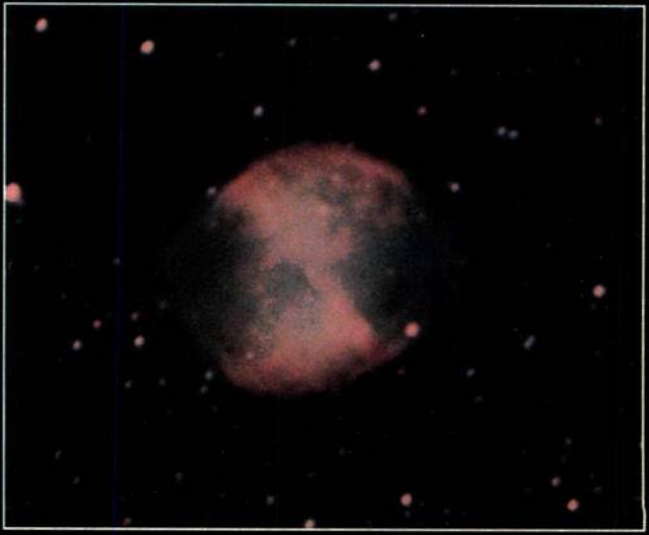


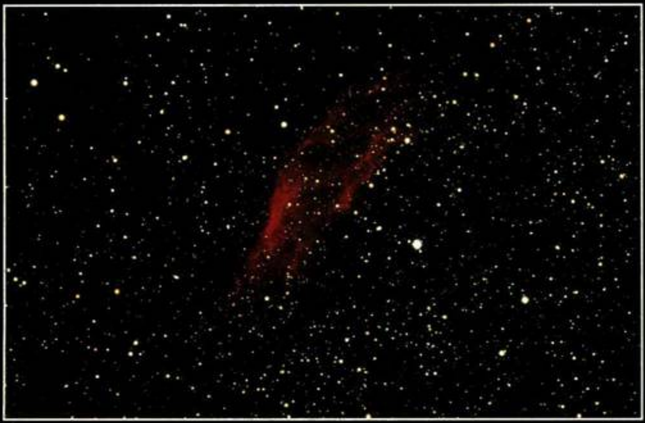
A small, dark cloud silhouetted against a faint strip of light, the Horsehead Nebula in Orion is generally regarded as a daunting target by astrophotographers. However, with persistence, careful planning, and skillful guiding, backyard astrophotographers can record faint objects like the Horsehead Nebula. This 20-minute exposure was made with an 8-inch f/1.5 Schmidt camera. All photos by Mace Hooley.



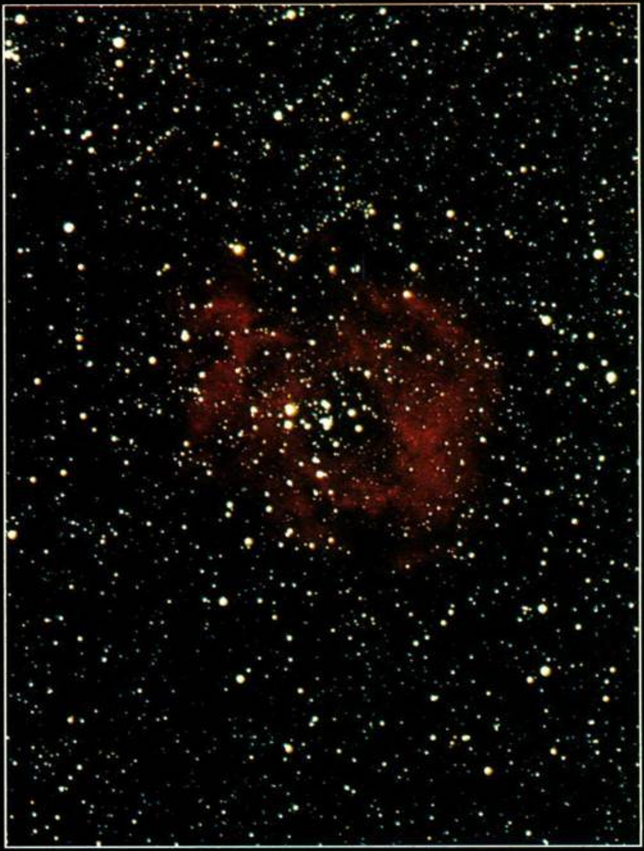
Above: Unphotographed by backyard astronomers until a few years ago, IC 2118 is a large, bluish reflection nebula near Orion's bright star Rigel. Called the Witch Head Nebula, IC 2118 is so faint that the author painstakingly sandwiched together two 30-minute exposures and made this composite photograph to show the nebula. The photographs were made with an 8-inch f/1.5 Schmidt camera, Fujichrome 100 film, and a 40ccm filter.

Right: Each year hundreds of astrophotographers record the Dumbbell Nebula in Vulpecula, but few record the nebula's faint outer detail. The Dumbbell Nebula's "ears," as they are called, require a long, carefully guided exposure under a dark sky. This is a 30-minute exposure on SR 1600 film, made with a 17.5-inch f/4.5 telescope.

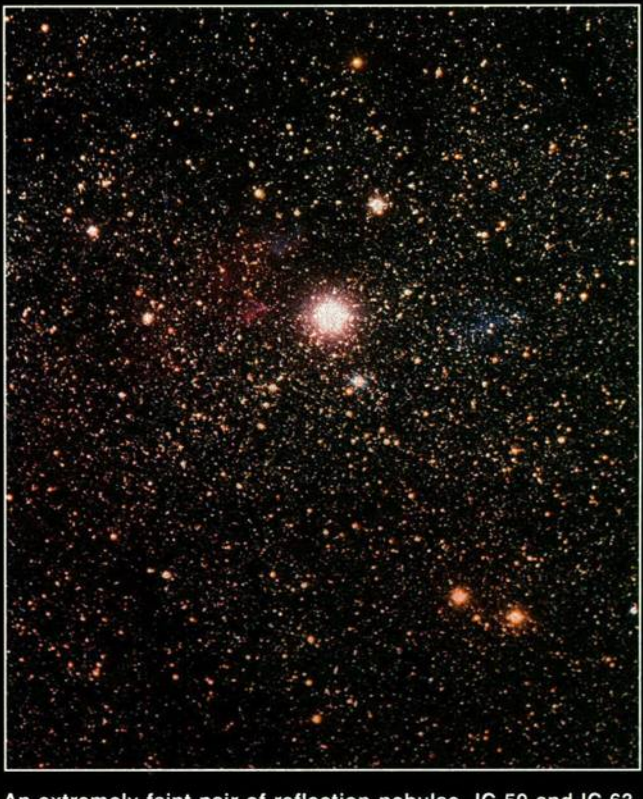




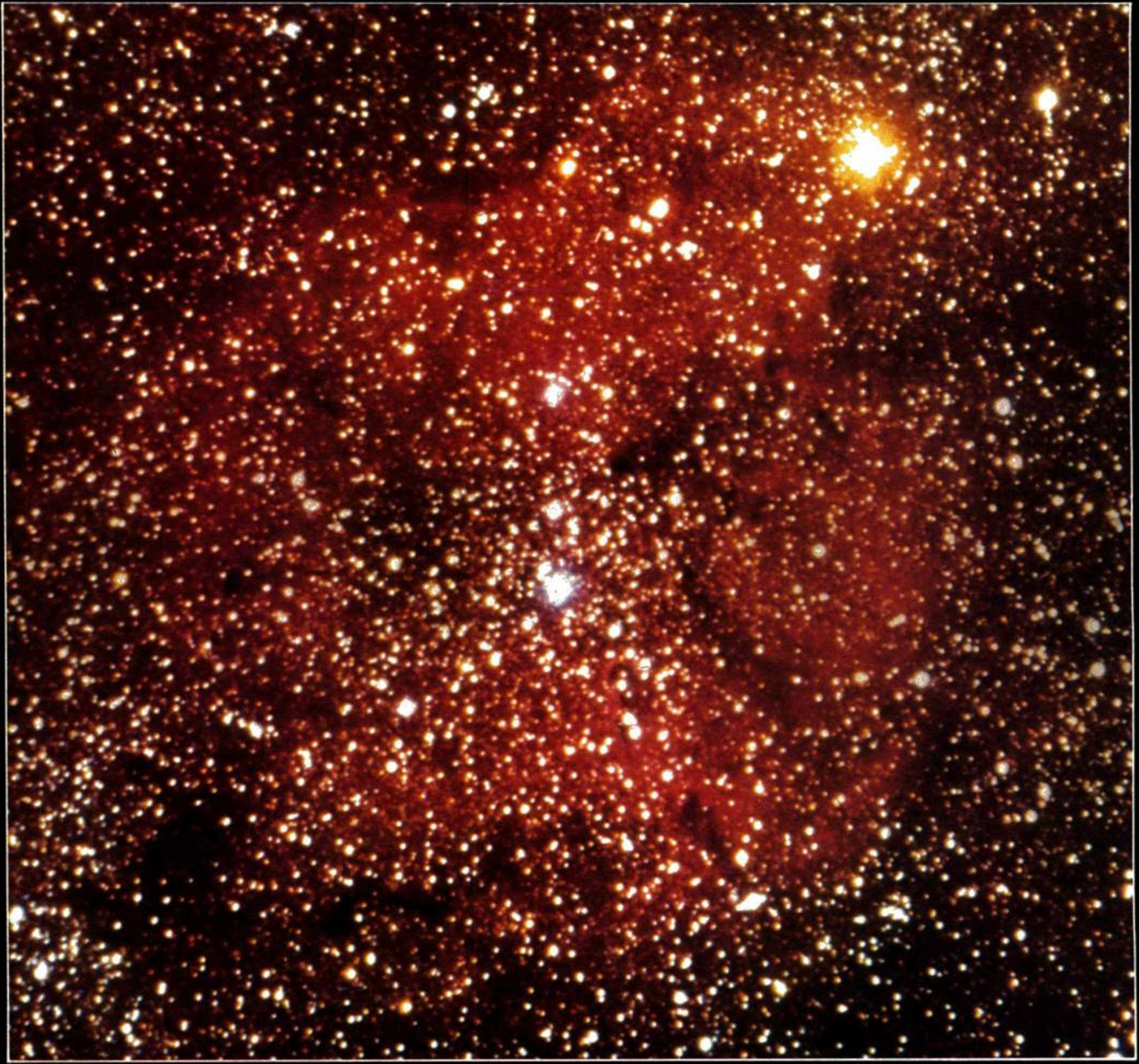
Resembling a giant "California in the sky," NGC 1499 in Perseus is one of the northern sky's faintest and most challenging emission nebulae. This photograph was made with an 8-inch f/1.5 Schmidt camera.



Glowing as dimly as the California Nebula is the Rosette Nebula in Monoceros. A faint, wreath-shaped nebulosity over 1° across, the Rosette contains a bright star cluster in its center. This photograph was made with an 8-inch f/1.5 Schmidt camera.



An extremely faint pair of reflection nebulae, IC 59 and IC 63, are visible just above and left of the bright star Gamma Cassiopeiae. If at first you don't succeed, keep trying: the author photographed this area several times before recording the nebulae. This is a composite of two 30-minute exposures.



The Cepheus Nebula is a great cloud of light south of the star Mu Cephei. It is visible in this composite photo of two 30-minute exposures made with an 8-inch f/1.5 Schmidt camera. A photograph like this is the payoff for many hours of preparation and careful photography.

20-minute exposures.

I loaded the film holder into the Schmidt camera, removed the cap to start the exposure, and guided away. Fifteen minutes into the first exposure, clouds rolled in. I interrupted the exposure by replacing the black cardboard "shutter" that covers the open end of the tube. Arizona was in the middle of monsoon season: the sky stays blue during the daytime, then clouds build up as evening approaches, only to clear again at dawn. That night, however, I was lucky. After ten minutes the clouds moved away and I finished the exposure.

Two more exposures followed. With three frames under my belt and the Cepheus Nebula still high in the sky, I decided to try a 30-minute exposure. After successfully completing it, I decided to push things to the limit and try a 45-minute exposure. I began hoping the No-Doz would really do what it's supposed to do.

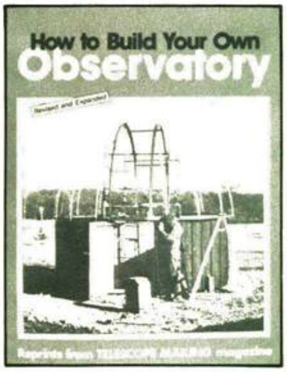
After four hours at the guidescope I felt my mind turning to mud. The sky looked ominously bright. Just a few hours ago I could not see the ground, but now I could read the exposure timer by starlight! The eastern horizon was slowly brightening, and the thin, waning Moon popped over the horizon. Soon the sky would be too bright for another exposure, so this one would be the last.

The night was over. As I packed up my astrophotographic gear, I could only wonder how many others were sacrificing their tires, gasoline, jobs, even their marriages to pursue astronomy. I wondered whether or not I had successfully captured the Cepheus Nebula. It turned out that I did. I ended up with a pretty shot of the nebula that is a composite of two 30-minute exposures.

All I could think was that if I hadn't tried, I wouldn't have succeeded. Capturing the Cepheus Nebula on film wasn't as difficult as I had thought it might be. Since that night I've recorded the faint light from many other objects, including the California Nebula in Perseus, the faint outer extensions of the Dumbbell Nebula, the Witch Head Nebula in Eridanus, and the Rosette Nebula. If you're intimidated by the really faint stuff, try photographing it anyway. With persistence and determination you'll discover that practically every nebula in the sky is within your reach.

Mace Hooley is an accomplished astrophotographer who lives in Yuma, Arizona. He co-authored "Taming the Schmidt Camera" in the December 1987 issue.

Revised and Expanded!



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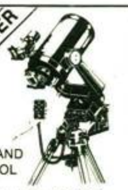

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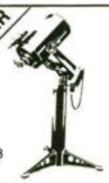

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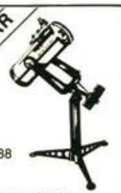

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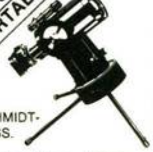

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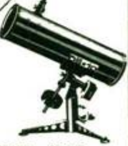

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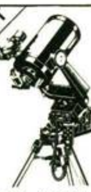

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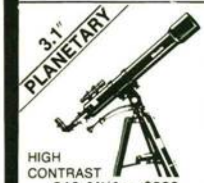

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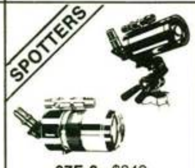

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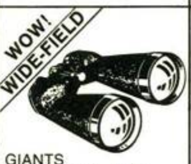

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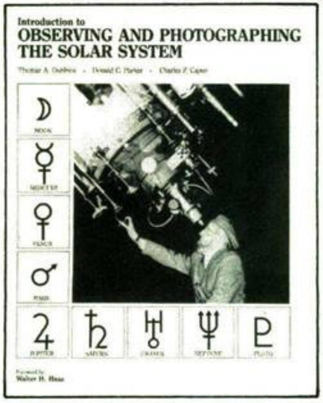
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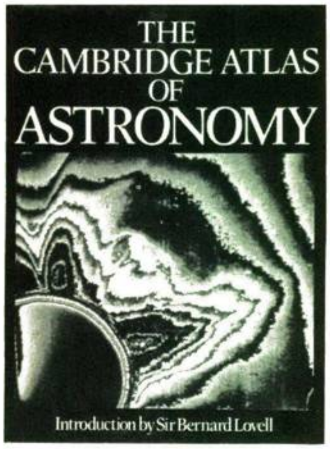
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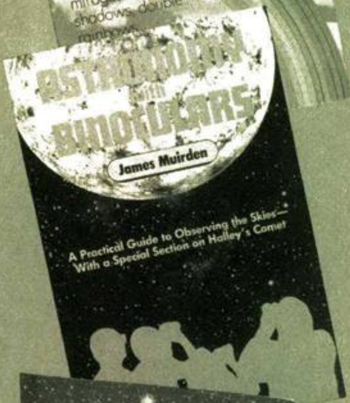
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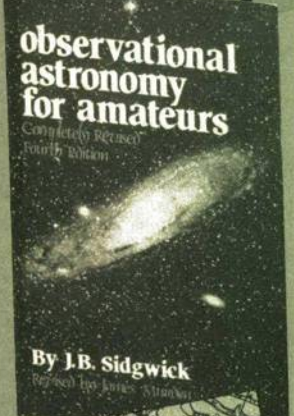
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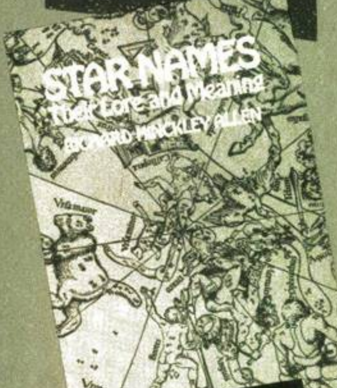
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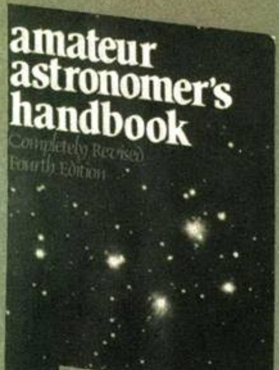
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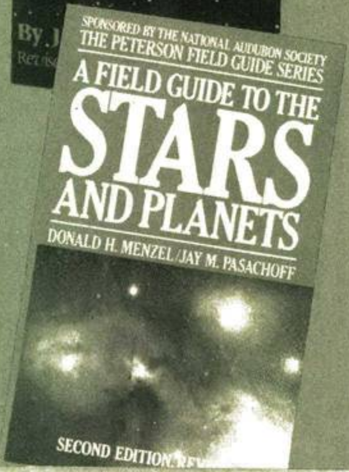
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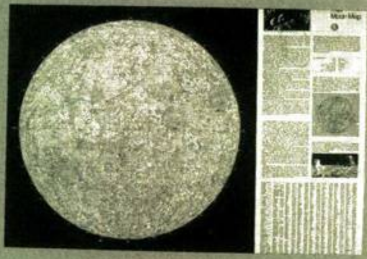

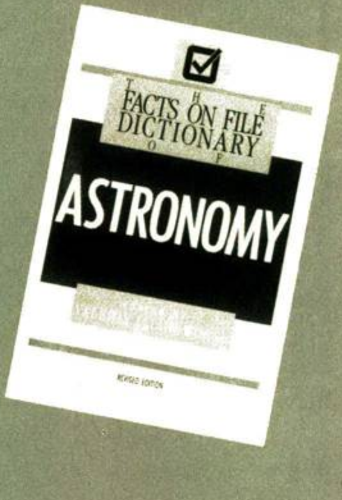
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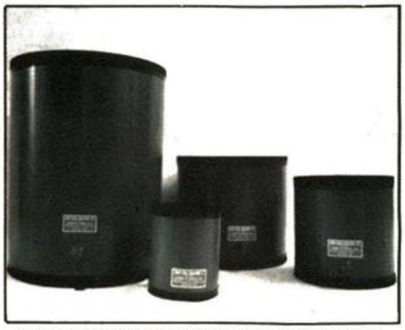
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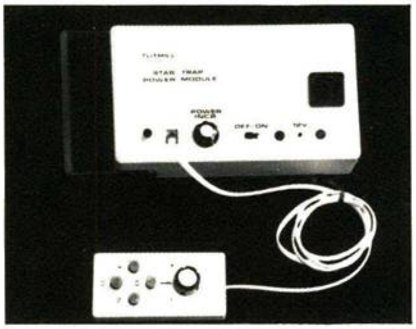

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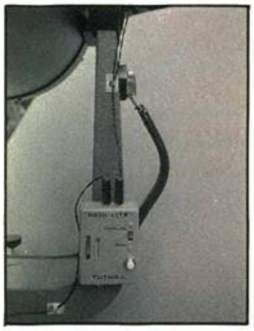
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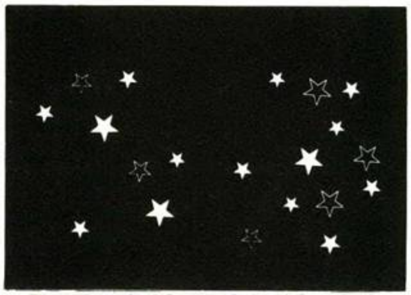
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A Telescope for Kids

Equipment
Atlas

by Peter Ceravolo

Kids should be able to enjoy the stars without climbing a stepladder or holding on to mom or dad for dear life. So I decided to build a pint-sized telescope. I call it the "Kneebiter" because it's so great for kids.

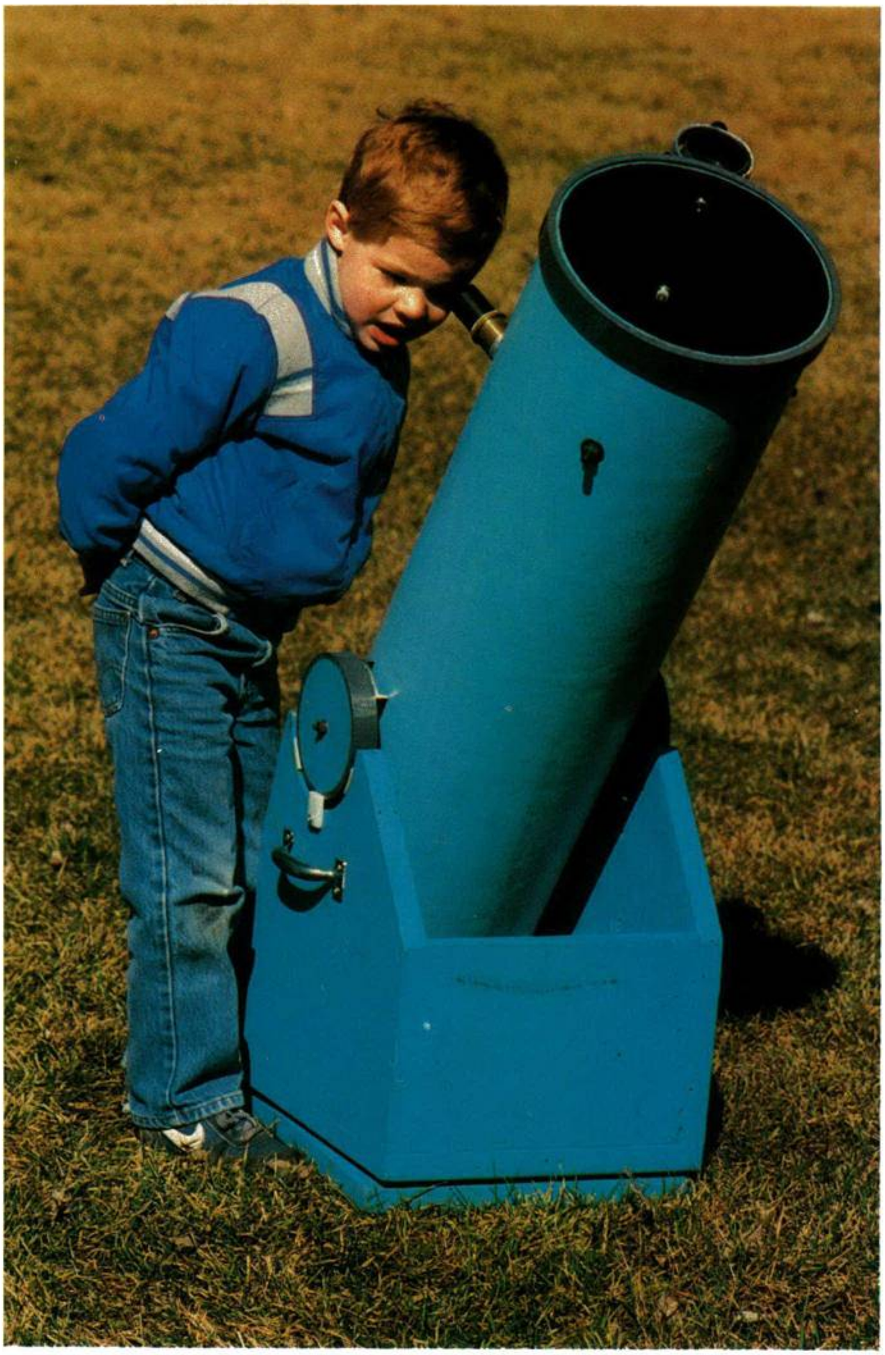
When I planned the Kneebiter, I tried to think of all the options. Because mediocre optics would defeat the purpose of the telescope, the Kneebiter should have the best optics available. I also wanted a scope that could be left in the car for impromptu observing sessions, which meant the telescope would have to be small. So I decided the optimal Kneebiter telescope should be an 8-inch f/4.5 Newtonian reflector on a Dobsonian mount.

Building the Kneebiter was a great project. The telescope is a joy for both kids and adults to use, and it's so simple that anyone with a little mechanical know-how could build one over the course of a few weekends.

Kneebiter Optics and Tube

For the Kneebiter scope's optics, I recommend an 8-inch f/4.5 primary mirror and a 2.25-inch by 3.15-inch diagonal mirror. This is a large enough primary mirror to show hundreds of objects in the sky, yet it keeps the physical size of the telescope small and the telescope low to the ground. I built my own Kneebiter with an 8-inch f/4 mirror I already had on hand — a Cassegrain mirror with a hole in the middle. However, though I used a mirror I happened to have on hand, I recommend that you purchase a normal 8-inch f/4.5 mirror from a commercial supplier (see page 81).

Before you purchase a set of optics, a word of caution: Make sure you get a well-figured mirror from a reliable manufacturer. When the mirror arrives, test it



Kids deserve telescopes too! A child's telescope should be low to the ground, easy to use, and unintimidating. The author's 8-inch "Kneebiter" telescope, made from scrap parts and an old set of optics, is a kid-friendly instrument. All photos by Peter Ceravolo.

carefully using the star test. For information on star testing, see "How to Star Test Your Telescope" by Dick Suiter (Equipment Atlas, April 1983), "Testing Paraboloidal Mirrors" by Dick Suiter (*Telescope Making #32*), or *Build Your Own Telescope* by Richard Berry.

The Kneebiter's tube is a 10-inch-diameter cardboard tube coated with Fiberglas. It is a so-called display tube, an item commonly used in construction. Display tubes are different from the "Sonotube" concrete-form tubes that many telescope builders use. Concrete-form tubes, used for pouring concrete pillars, have a thick wax coating on the outside. It is necessary to remove this coating before using the tube. Display tubes are the same thing without the wax coating, so they are easier to use.

Deciding the tube length is critical in planning the Kneebiter. For the 8-inch f/4.5 mirror, I recommend that you make the tube 46 inches long. This allows you to extend the tube about a foot past the focuser, which gives you a built-in "lens hood" that prevents stray light from entering the tube. If light does enter the tube, it scatters inside the telescope and lowers the contrast of astronomical images, which results in a "washed-out" appearance in the eyepiece. After you decide on the tube length, either cut the section of tube yourself or have the building supply outlet do it for you. Your own little kneebiter will have fun helping you saw the tube.

To strengthen the tube and protect it from moisture, I covered the exterior with Fiberglas cloth and brushed the interior with several coats of resin. If you can, consult the experts who work at the stores you buy your supplies at for instructions on covering and coating the tube or check the "how to do home repairs" section of a library. Many books on boat repairs contain information about using coating resins and Fiberglas cloth because these items are used for hulls. By the way, Fiberglas resin is messy, toxic, and possibly carcinogenic. Keep your kid's sticky fingers out of this part of the job.

The tube rests in its mounting supported by altitude bearings. These are simply 5-inch-diameter sections of PVC tubing cut in one-inch widths. Glue a wooden disk inside the PVC tubing to strengthen the plastic and make it rigid. You'll now have a solid disk made of wood and plastic. To mount this disk onto the side of the telescope tube, use either two wooden strips or an aluminum U-channel fastened to the wooden disk and a large bolt to connect the disks to each side of the tube.

Add a heavy-duty handle at the telescope's center of gravity. The handle will make the telescope easy to carry. Buy the largest handle you can find, because you'll probably want to fit a gloved hand inside it so you can carry the telescope without hurting your hand.

I added an access door on the side of the tube on my Kneebiter, so I could place a cover over the mirror after each observing session to protect the mirror from dust. This is a handy feature but was a lot of work and not essential. (Besides, curious kneebiters might open the door!)

Mounting the Optics in the Tube

To support the mirror, I used an unusual mirror cell/end ring combination. I melted together 3/8" thick PVC pipe and PVC sheet stock with a heat gun. The pipe was just the right size to fit snugly over the end of the tube, capping the tube and preventing dust and stray light from creeping in. The cell itself is a spring-loaded, three-point cell. This type is easy to adjust and is sturdily made, which minimizes the likelihood of the mirror moving out of alignment.

For your mirror, either build a mirror cell or buy one from a commercial supplier (see box). Because the mirror mount is somewhat tricky, the easiest solution is a commercial mount. However, if you decide to build one, only modest effort is required.

To build the mirror mount, first cut a disk of wood 8 inches in diameter. Next, take three 2-inch-long aluminum strips and bend them into "L" shapes (see diagram). After getting a uniform "L" shape, bend the tip of the aluminum pieces to form a little clip that will hold the top of the mirror. Place the aluminum clips equidistantly to hold the mirror to the wooden disk. The mirror should rest on cork pads inserted to protect the glass surface, and the wooden disk is supported by three push-pull bolts that extend through the back end of the tube. These bolts allow you to adjust the mirror's alignment. For an alternate strategy in mirror mounting, see *Build Your Own Telescope*.

The most complex part of the tube assembly to build is the secondary mirror mount and spider. I was fortunate to have access to a band saw and drill press, which made construction of these parts possible. Still, fashioning some of the 45°-angled cuts was tricky, and working with thin steel sheet stock for the spider is not easy. I strongly suggest that you purchase the secondary mount and spider from a commercial supplier instead of building them.

Accessories for Your Kneebiter

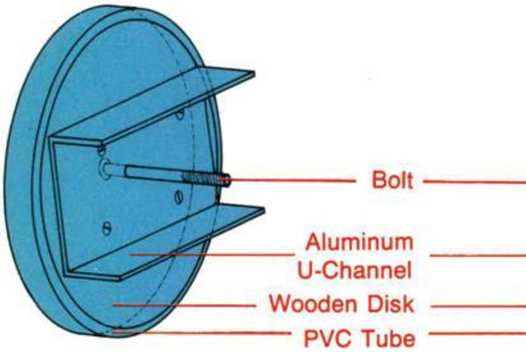
You need to pay special attention to three critical tube accessories. The focuser you use will greatly affect the telescope's overall performance. Regardless of the type of focusing mechanism you choose — rack and pinion, helical, or otherwise — make sure that you mount the focuser as low as possible. I mounted my focuser "inboard" to keep its height above the tube at a minimum. This reduces the size of the secondary mirror needed to provide full illumination at the eyepiece. By minimizing the secondary mirror's size, I also minimized obstruction of the telescope's light path.

A finder scope is important because it's

The 'Kneebiter'

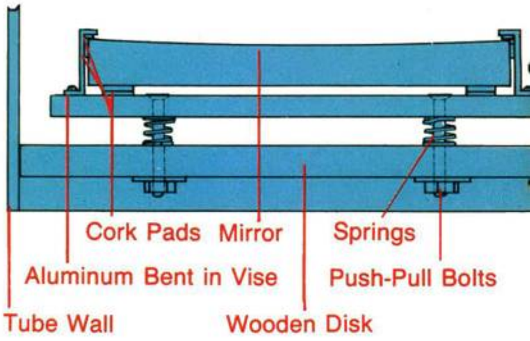
Side Bearings

The side bearings attach to the tube and support the tube inside the Dobsonian mount. They also allow smooth up/down movement.



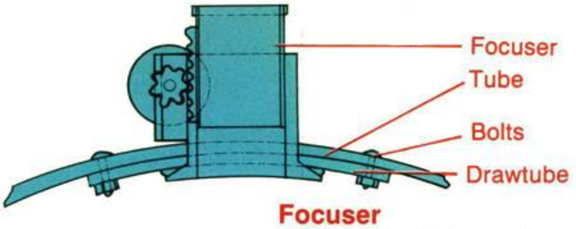
Mirror Cell

The Kneebiter uses a simple mirror cell that holds the mirror firmly in place even if the telescope is roughly handled.



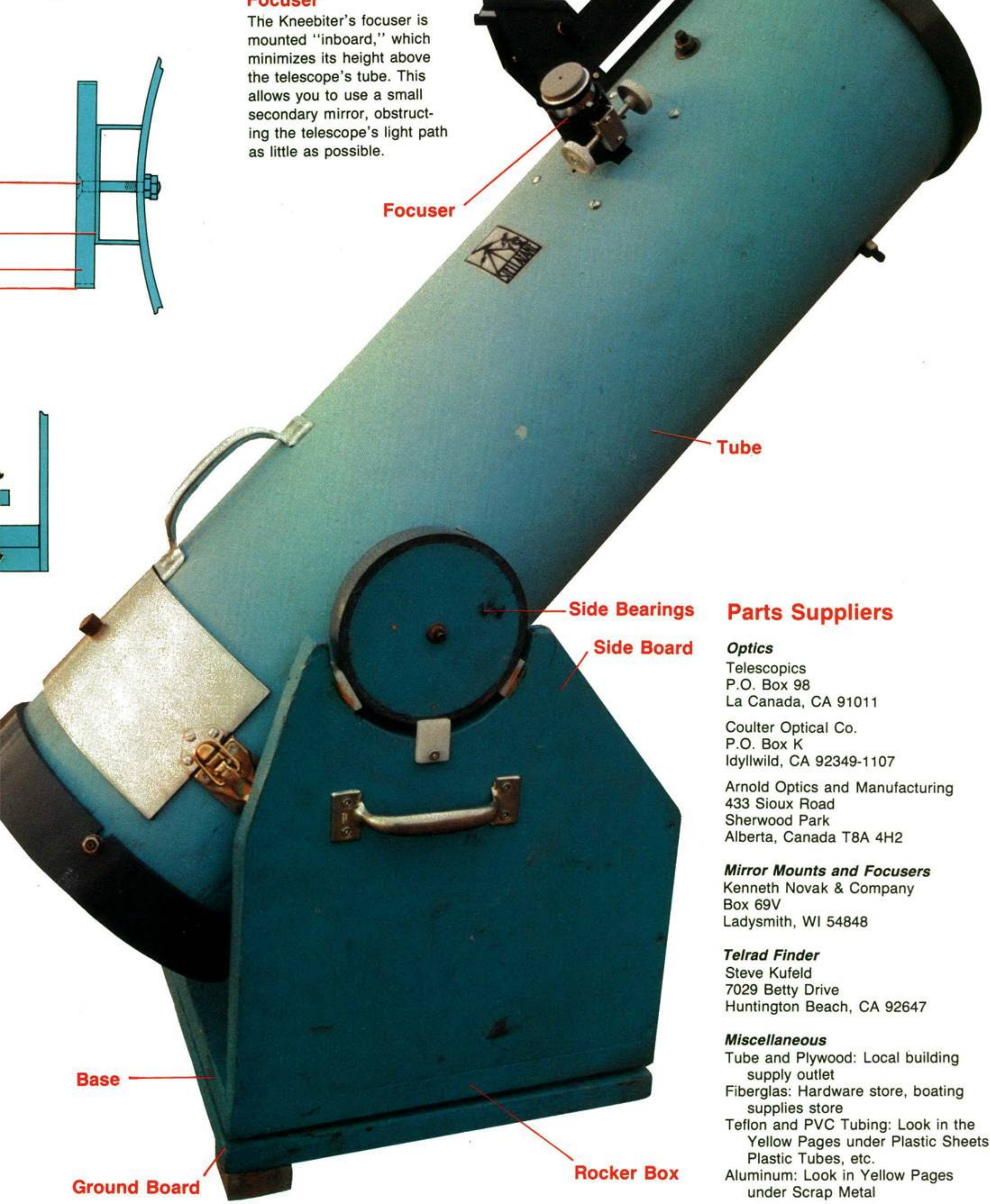
Parts for the Kneebiter

8-inch f/4.5 primary mirror
2.25-inch minor-axis secondary mirror
Primary mirror cell
Secondary mirror holder
10-inch-diameter display tube measuring 36 to 42 inches long
PVC pipe for end ring, 1 inch wide with 10-inch inside diameter
Fiberglas cloth
Quart of resin with hardener
Paint
1.25-inch focusing mount
Telrad finder scope
Three large handles
Two 1-inch-long sections of PVC tubing, 4 to 5 inches in diameter, for declination bearings
Two 1-inch-thick wooden disks to press-fit into declination bearings
Two aluminum or hardwood U-channel extrusions, 2 inches wide, as long as diameter of declination bearings
Nine pieces of Teflon, each measuring 1.25 inches by 1 inch by 0.25 inch
1-inch-thick plywood for Dobsonian mount
Three aluminum or hardwood 2-inch squares, each 1 inch thick
Formica for underside of rocker


Focuser
Tube
Bolts
Drawtube

Focuser

The Kneebiter's focuser is mounted "inboard," which minimizes its height above the telescope's tube. This allows you to use a small secondary mirror, obstructing the telescope's light path as little as possible.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Teflon and PVC Tubing: Look in the Yellow Pages under Plastic Sheets, Plastic Tubes, etc.
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The Kneebiter is small enough to fit inside the trunk of a small car when you want to transport the telescope to a dark-sky site. The telescope is light enough to be handled easily by one adult.

difficult to use a telescope without one. At first I tried a standard 50mm finder on my Kneebiter. However, I soon realized that such a finder wasn't necessary because the telescope itself had a wide enough field of view to easily find most objects. I recommend the Telrad one-power finder for your Kneebiter. This device projects a series of concentric red rings onto the sky as you look through it and shows you exactly where the telescope is aiming. The Telrad is easier to use and less expensive than a normal finder scope. Besides, kids intuitively understand how the Telrad works.

Eyepieces are another important accessory to consider. Your favorite kneebiter deserves good optics, but there are limits. Eyepieces that cost hundreds of dollars apiece clearly aren't "kid's stuff." On the other hand, Edmund's RKE eyepieces are great for kids. At a public star party with lots of kneebiters running around, it would be extremely wise to use these inexpensive eyepieces.

For adults, I recommend the modern ultra-wide-angle eyepieces by TeleVue or Meade. These were designed with short-focus telescopes in mind. They provide good star images over an entire, incredibly wide field. The RKE eyepieces make good back-ups if you don't have that kind of moolah.

The Dobsonian Mount

I built the Kneebiter's mount from material and components I had on hand. Whether or not you have scrap materials to use, I recommend building a simple Dobsonian mount to hold the Kneebiter's tube, because Dobsonian mounts are ideal for low telescopes that have to be sturdy.

A Dobsonian mount consists of a ground board that sits on the ground. The ground board has three small wooden blocks on its underside that sit on the ground. Mount three Teflon pads in a triangle on the top of the ground board. The Teflon pads support the rocker box, which in turn holds the telescope. This allows the rocker box to rotate smoothly in azimuth.

The rocker box is made of a base board with Formica on the bottom, two side boards that support the telescope's bearings, and a front board to anchor the side boards solidly to the base and prevent wobbling. The rocker box has to be deep enough and wide enough for the telescope to swing inside without hitting anything. The outer width of the rocker box should be equal to the distance between the outer edges of the altitude bearings so the telescope can rest in the mount.

Two small Teflon pads hold the altitude bearings in place so the telescope can swing up and down. On my mount I extended the front end of the rocker so the tube could easily swing well past the zenith. This gives the telescope a little more freedom of movement than it might otherwise have.

Because the dimensions of your tube will probably be different than the dimensions of my tube and because I used what happened to be in my scrap box, you will have to determine the exact sizes and material to use on yours. Make scale drawings of the tube assembly with all the parts in place before you start drilling holes. I used 1-inch-thick plywood throughout. Three quarter-inch plywood will work just fine, and the resulting mount will be a bit lighter than mine is. For additional information, see "How to Build a Dobsonian Telescope" by Bob Kestner and Richard Berry (Equipment Atlas; June, July, and August 1981), "How to Plan a Newtonian Reflector" by Richard Berry (Equipment Atlas, March 1982), and *Build Your Own Telescope*.

The Kneebiter is the perfect telescope for kids. The telescope is also perfect for observing the Milky Way star clouds and nebulae. With the addition of a Barlow lens to increase magnification, the telescope is ideal for the Moon and planets, which is what the little kneebiters *I* know love best. And best of all, you can easily build one yourself.

Peter Ceravolo is a professional optician and president of the Edmonton Centre of the Royal Astronomical Society of Canada. His last article was "Seeing a Vampire in the Mirror," which appeared in the October 1987 issue.

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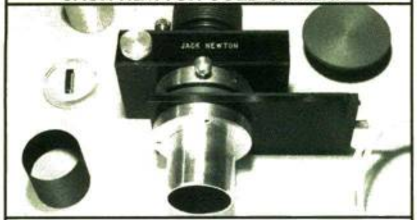

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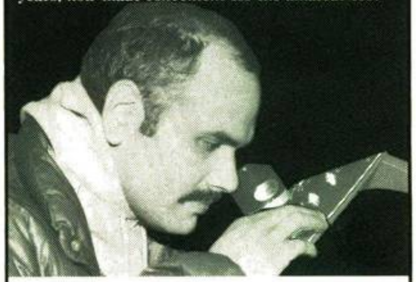

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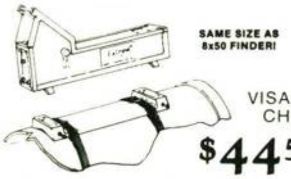
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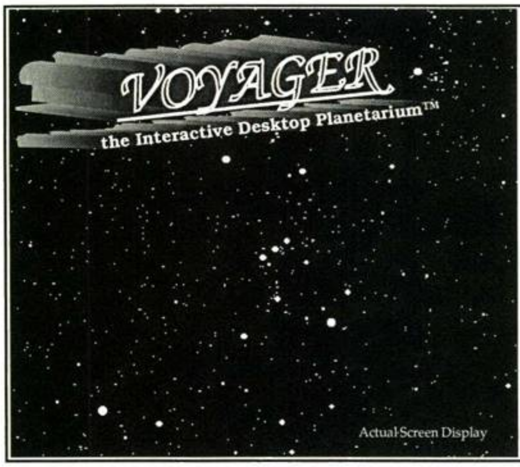

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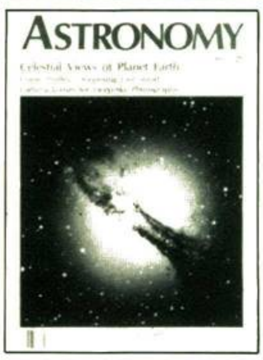

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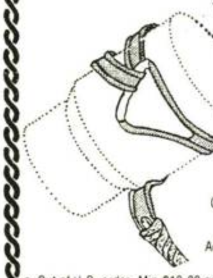

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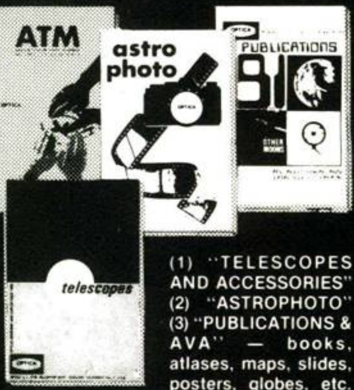

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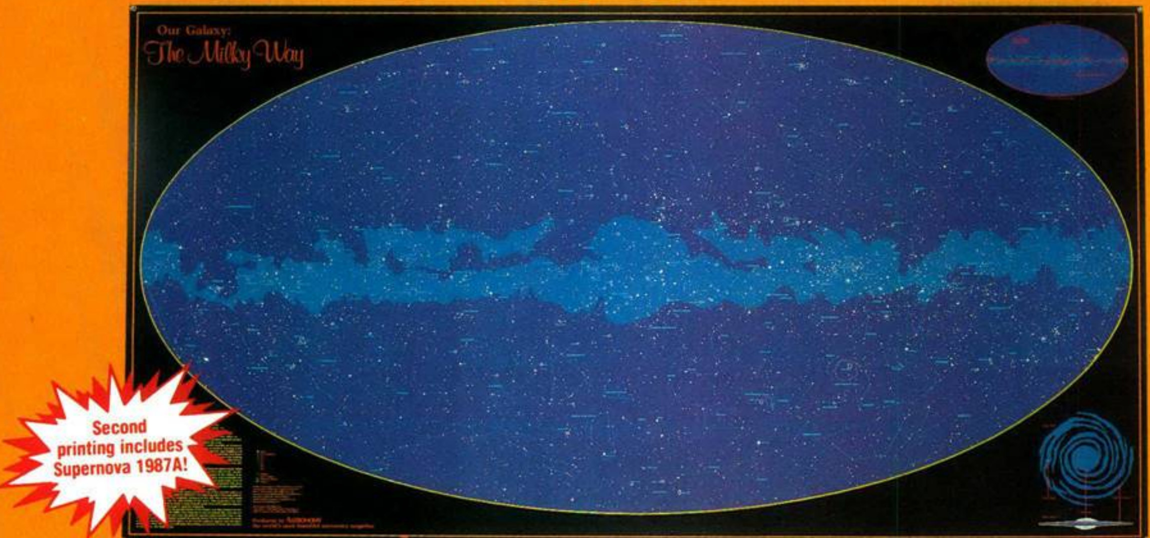

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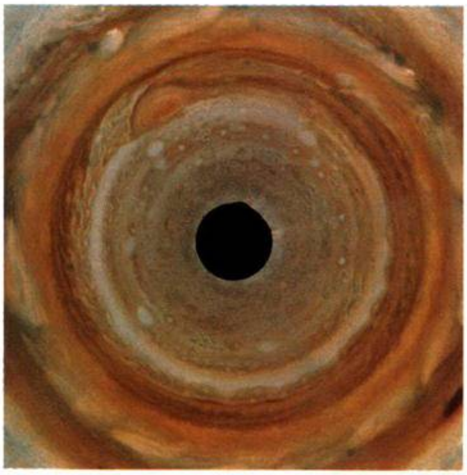
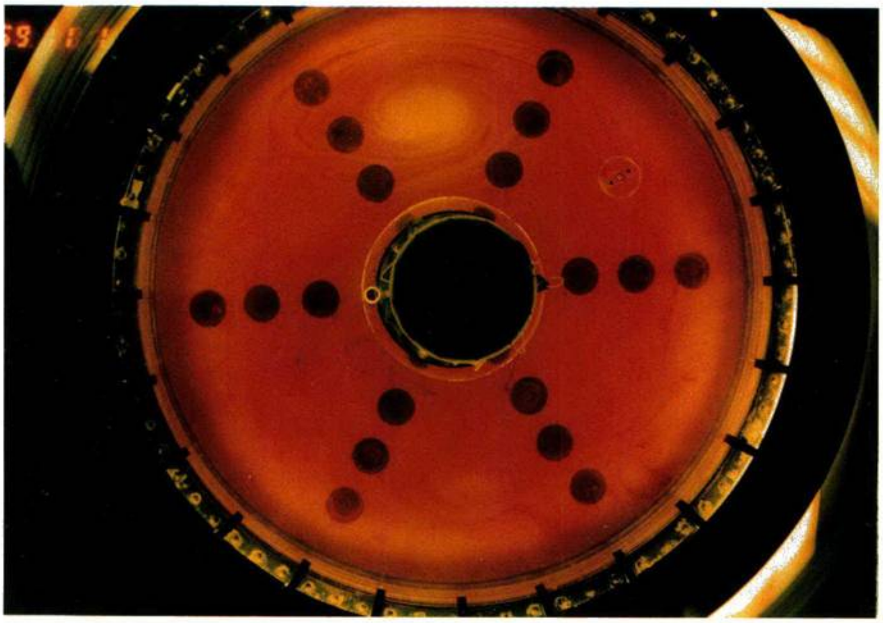
AstroNews

The Great Red Spot Comes to Earth





Scientists have long wondered how Jupiter's Great Red Spot — visible at the upper left in the *Voyager* composite image showing the planet's south pole (top) — could survive for over three hundred years in the turbulent Jovian atmosphere. University of Texas at Austin researchers Joel Sommeria, Steven Myers, and Harry Swinney have simulated the Red Spot by using a rapidly rotating circular tank of water. They pumped water from an inner ring of inlets to a middle ring of outlets (the regular pattern of black circles in the photo above). This outward flow created a counter-rotating current, and vortices formed in the region of interaction. Dye injected into the water mixed rapidly with the turbulent flow around the vortex but could not penetrate the spot.

Manned Exploration, Private Launch Industry Goals of New Space Policy

President Reagan's long-awaited policy statement on the U.S. space program, released in February, calls for the expansion of man's presence beyond Earth orbit and the establishment of a commercial launch industry that will play a key role in the country's overall launch capability.

"The policy clearly establishes for the first time that the United States has a long-range goal of expanding human presence and activity into the solar system," said James Fletcher, NASA Administrator, at a press briefing on the new policy. "This is a goal of enormous significance with potentially historic future implications."

The policy statement is the result of a five-month, interagency review of civil, military, and commercial space policies and reports, including the President's National Commission on Space report completed in 1986 (see AstroNews, September 1986).

The new policy also seeks to preserve the nation's "pre-eminence" in space science and manned flight, to establish a permanently manned Space Station by the mid-1990s, and to increase international cooperation in civil space programs.

Though the space shuttle is to remain an important part of the nation's launch capability, the policy mandates that it will no longer be the sole launch system. Instead, a variety of launch vehicles, including expendable launch vehicles (ELVs) provided by the private sector, will be used.

"The policy is now set out that U.S. space transportation systems must provide a balanced, robust, and flexible capability with sufficient resiliency to allow continued operations despite failures of any single system," said Secretary of Transportation James Burnley.

According to the policy, the government will move toward the commercialization of unmanned launch vehicles. "The policy shifts major responsibilities for space development from the public to the private sector," said Secretary of Commerce C. William Verity.

"But it is not a policy that takes from one sector and gives to another," said Verity. "It is a policy that takes advantage of the strength of both sectors. The private sector, which makes investments at the risk of failure, is innovative and dynamic. The government is strong on research. This policy frees government researchers to let their imaginations run free and develop new concepts and processes."

"If we can get the ELV load off of our back and give it all to the private sector," said Fletcher, "that will allow NASA to turn its attention more to research and development. I believe that's the intent of the President's program."

The policy directs NASA to begin a research program, called Pathfinder, to develop new technologies required for manned missions and manned bases on the Moon and Mars. According to Fletcher, "Pathfinder will permit a future administration to act with competence in deciding on specific manned exploration goals."

Most Distant Object in Universe Discovered

Astronomers have found a quasar so distant that it represents looking back in time toward the "epoch of creation," the beginning of the universe some 15 billion years ago. The object, designated Q0051 −279, was discovered in December 1987 by two Cambridge University astronomers and is the most distant object known in the universe. Q0051 −279 has a redshift of 4.43, which places it approximately 12 billion light-years away and means it is receding from us at 93 percent of the speed of light.

Astronomers Stephen Warren and Paul Hewett found the quasar using the 3.9-meter Anglo-Australian telescope at Siding Spring, Australia. Working with Warren and Hewett on the same project, Patrick Osmer of the National Optical Astronomy Observatories (NOAO) discovered the *third* most distant quasar, Q0101 −304, which has a redshift of 4.07. Osmer used the 4-meter telescope at Cerro Tololo, Chile.

The scientists are clearly excited by the chance to look so far back into the history of the universe. "We are looking for the epoch of formation," said Osmer. "We have the power to do so. Existing telescopes could see things with a redshift of 5 or more. Where galaxies fall below our threshold of detection at relatively low redshifts, quasars seem to run out before we reach our limit of detection."

The discoveries resulted from a close collaboration of Cambridge and NOAO scientists who worked on hardware and data reduction separately and then pooled their efforts. The astronomers used a

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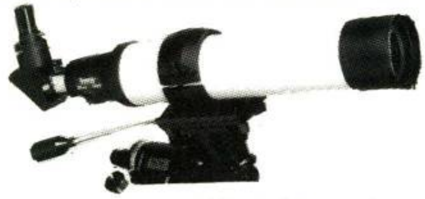

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But the APM could only contribute so much. After getting a list of eighty good candidates for high-redshift quasars, the group examined the spectra of these candidates using the Anglo-Australian telescope and the Cerro Tololo 4-meter instrument. Among the eighty candidates the astronomers found two with enormously high redshifts, Q0051 −279 and Q0101 −304.

The Mystery of Nova Cygni Solved

Astronomers have found that Nova Cygni 1975, one of the brightest novae of this century, contains a highly magnetized white dwarf star — the first ever recognized in a nova system. The discovery explains unusual variations in the nova's light curve and odd spectral features observed by astronomers since August 1975 when the nova erupted in brightness.

Peter Stockman of the Space Telescope Science Institute, Gary Schmidt of the University of Arizona's Steward Observatory, and Don Lamb of the University of Chicago's Enrico Fermi Institute report that new observations of the nova remnant, now designated V1500 Cygni, show that the magnetic field produced by the system's white dwarf is some 10 million times stronger than the one surrounding Earth. (Novae systems contain two stars: a white dwarf and a normal, main sequence star.)

Astronomers first noticed something odd about Nova Cygni 1975 shortly after it erupted and was observed by professional and amateur astronomers worldwide. Investigators found the nova went through unexpected 3.3-hour oscillations in brightness, visible at first in the nova's emission lines and later across its optical spectrum. This strange behavior was compounded by the significantly speeded up fluctuations during the two years following the eruption.

Some astronomers suspected that the light variations were somehow related to the orbital period of the pair of stars in the Nova Cygni 1975 system. One scientist proposed that the energetic white dwarf illuminated one side of the main sequence star, and the bright side of the star appeared and disappeared as the star rotated, causing the fluctuation in brightness.

However, this idea did not explain the system's changing period. And as the nova faded, so did astronomers' interest. According to Stockman, "The data were so chaotic [that the nova] was puzzled over but largely forgotten. No model ever satisfactorily explained the observations."

Stockman's interest in the nova was rekindled when he and fellow researchers found that the flickering and strange emission spectrum of V1500 Cygni resembled that of a bizarre class of variable stars called AM Herculis stars.

Like the nova remnant, AM Herculis stars are binary systems showing short-term variability and odd spectral features. Broad emission lines and x-ray emission from AM Herculis systems suggest that these systems contain a white dwarf star drawing gas off the cooler companion star and superheating the material to well over 100 million degrees. The most distinctive spectroscopic feature of AM Herculis stars is circular polarization, which is visible in their emission spectra. Circular polarization is produced when electrons spiral along the field lines of an extremely strong magnetic field.

Between March and October 1987 Stockman observed V1500 Cygni, looking for circular polarization. If he found it in the remnant's spectrum, it would confirm the presence of a magnetic white dwarf in the V1500 Cygni. Every time Stockman observed the V1500 system he detected circular polarization in its spectrum.

The discovery explains why Nova Cygni 1975 at first rapidly increased and then rapidly decreased in brightness. Because the white dwarf's intense magnetic field controlled the flow of infalling gas from the companion star, a great amount of fuel for the nova's eruption accumulated on the dwarf's surface. Material funneled onto the dwarf's surface at a shock point near one of the star's magnetic poles. Following the outburst, the nova quickly dimmed because the dwarf star's magnetic field prevented new infalling gas from accumulating near the star. The star's changing period was caused by radiation streaming off a point on the white dwarf, probably the shock point, and reflected the rotation of the white dwarf itself.

Stockman expects to study the star with the 5-meter Hale telescope at Palomar Observatory in California. Over the next decade he expects the system to fade. However, Stockman suggests it may erupt again in about 100,000 years.

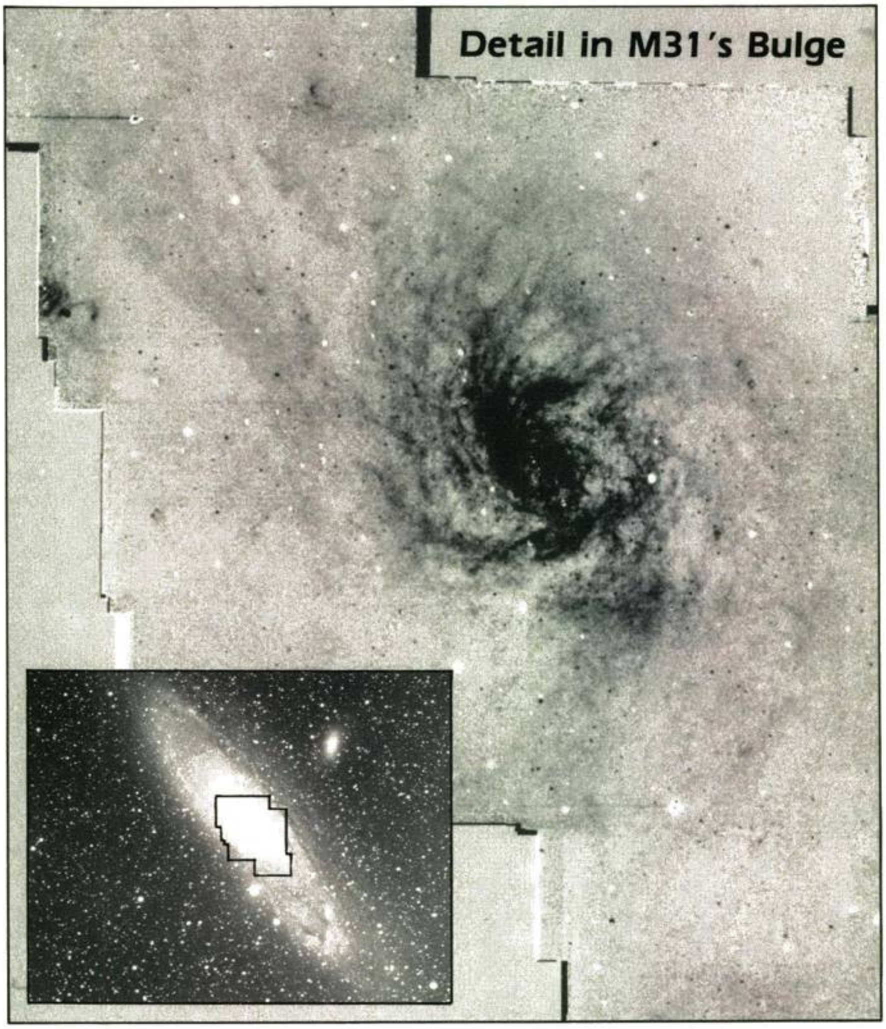
Explanation Offered for Outcast Open Clusters

A small number of open clusters known to be located far from the star-crowded disk of the Milky Way may have formed in gas clouds blasted free of the disk by supernova explosions. According to Kenneth Janes, associate professor of astronomy at Boston University, no other explanation can adequately explain the presence of these clusters in the galactic halo.

Most of the open clusters in our Galaxy are distributed throughout the thin disk called the Milky Way, where dense regions of gas facilitate star formation. The Pleiades, the Hyades, and the Double Cluster are typical examples of these stellar aggregates. However, a small number of clusters are located in the galactic halo. At least fifteen clusters are more than 400 parsecs from the plane, and four are more than 1,000 parsecs from the plane.

For years astronomers have proposed various theories to explain the presence of these out-of-place open clusters. Some astronomers believe these clusters were ejected from the Milky Way by collisions with giant molecular clouds — huge clouds of cool, dense interstellar material in which atoms are likely to combine into molecules — or that the clusters formed in highly eccentric orbits that took them out of the Galaxy's disk.

But Janes takes issue with both explanations. The energy required to eject a cluster from the Milky Way, he claimed, would likely disrupt the cluster. "The ejection velocity needed to propel the cluster out of the plane of the Galaxy," said Janes, "is ten times the binding energy of the cluster."



Detail in M31's Bulge

This new image of the Andromeda Galaxy (M31) leads astronomers to believe the galaxy's inner disk is not oriented the same way as the rest of the galaxy (inset). This suggests that the ionized gas in the center of M31 is not in the same plane as M31's optical disk. The disrupted gas in the bulge may result from supernova-generated "galactic winds" flowing out from the center and into the interstellar medium.

One of the most conspicuous features is a 1,500-parsec-long arm of hot gas curving around the southern half of the bulge. The arm appears to be nearly circular, and this strongly suggests that the gas in this region is more face-on than the galaxy's optical disk, which is tilted 77° to our line of sight.

Another conspicuous feature of the image is the lack of comparative symmetry in the gas on the southeastern and northwestern sides of the bulge. Taken together, these features indicate that the plane of gas in the bulge may be warped and not coincident with the plane of the optical disk. North is at top and west to the right in both photos.

(Andromeda Galaxy photo courtesy of Yerkes Observatory; bulge photo courtesy of Robin Ciardullo, National Optical Astronomy Observatories.)

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Instead, the clusters must have been moving rapidly enough at the time they formed to break away from the gravitational hold of the disk. However, the vast majority of clusters, Janes said, "appear to form in such a manner that they move in paths that keep them close to the Milky Way plane. There must be some hitherto unrecognized mechanism to give a kick to some star clusters as they formed."

Janes speculated that the mechanism involves supernova explosions. Gas clouds could be boosted out of the plane of the Galaxy by single or multiple supernova explosions. Stars might later form in the cloud, even though the cloud's motion would eventually carry its associated stars outside the plane of the Galaxy.

In addition to lying at greater distances from the galactic disk, halo open clusters differ from disk open clusters in two other respects, said Janes. Halo open clusters are substantially more massive than ordinary clusters, and they range widely in age from less than 1 billion to almost 10 billion years. In contrast, the lifespan of most disk-type open clusters is a few hundred million years. Janes speculates that the two apparently different distributions might represent distinct populations: near- and far-plane open clusters.

Janes presented his ideas during last January's meeting of the American Astronomical Society in Austin, Texas.

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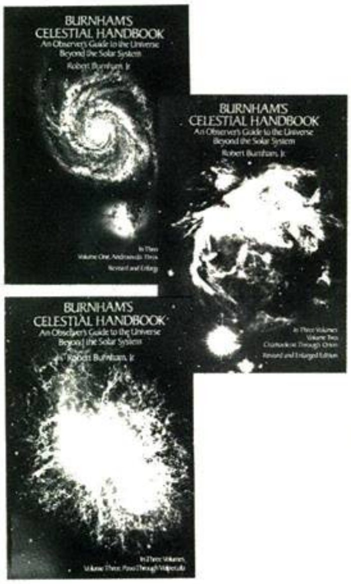
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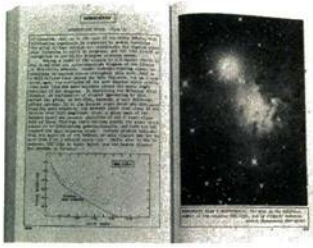

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ASTRONOMY
AstroCalendar

May 9-15
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP Registrar, 6433 Cedar Hollow, Dallas, TX 75248.

May 14
14th Annual Virginia Association of Astronomical Societies Convention (sponsored by the Back Bay Amateur Astronomers), South Hampton Roads, Virginia. Contact: Glen Howell, 2808 Flag Road, Chesapeake, VA 23323.

May 14
North Central Region of the Astronomical League Annual Convention (hosted by the Marquette Astronomical Society), Northern Michigan University, Marquette, Michigan. Contact: Jeanne Shibley, Registrar, 412 High Street #1, Marquette, MI. Phone: (906) 225-1066.

May 21-22
Space Expo (spacecraft exhibits), Cradle of Aviation Museum, Garden City, New York. Contact: J. Stoff, Cradle of Aviation Museum, Museum Lane, Mitchel Field, Garden City, NY 11530. Phone: (516) 222-1190.

May 27-30
Riverside Telescope Makers Conference, Camp Oakes, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92503. Phone: (714) 689-6893.

June 5-9
172nd Meeting of the American Astronomical Society (professional meeting), University of Kansas, Kansas City, Missouri. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009.

June 10-11
Apollo Rendezvous and Telescope Fair (sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History), Dayton, Ohio. Contact Ian Dumbauld, Miami Valley Astronomical Society, 2629 Ridge Avenue, Dayton, OH 45414.

June 10-11
Arkansas Star Party (sponsored by the Arkansas—Oklahoma Astronomical Society), Douglas C. Coleman Memorial Observatory, south of Fort Smith, Arkansas. Contact: Arkansas–Oklahoma Astronomical Society, Route 3, Box 421W, Pocola, OK 74902.

June 17-19
13th Annual Association des Groupes d'Astronomes Amateurs Congress (sponsored by the Royal Astronomical Society of Canada, Quebec Center), Sainte-Foy, Quebec, Canada. Contact: R.A.S.C., Quebec Center, P.O. Box 9396, Sainte-Foy, Quebec, Canada G1V 4B5. Phone: (418) 626-9592.

June 18
25th Annual Ohio Turnpike Astronomers Association Convention (hosted by the Cuyahoga Astronomical Association of Cleveland), Hiram College, Hiram, Ohio. Contact: Robert Fritz, Cuyahoga Astronomical Association, P.O. Box 29089, Parma, OH 44129. Phone: (216) 237-3620.

June 25-26
The Universe in the Classroom (weekend credit workshop on teaching astronomy in grades 3-12 for U.S. and Canadian teachers, sponsored by the Astronomical Society of the Pacific and the Royal Astronomical Society of Canada), University of Victoria, Victoria, British Columbia, Canada. Contact: Teachers Workshop, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.

June 25-July 2
100th Annual Meeting of the Astronomical Society of the Pacific, jointly sponsored by the Royal Astronomical Society of Canada and the Western Amateur Astronomers, University of Victoria, Victoria, British Columbia, Canada. Contact: A.S.P., Summer Meeting Department, 1290 24th Avenue, San Francisco, CA 94122.

June 29-July 3
International Planetarium Society Convention, Richmond, Virginia. Contact: Ken Wilson or Eric Melenbrink, Universe Planetarium, 2500 West Broad Street, Richmond, VA 23220. Phone: (804) 257-0211.

July 16-17
18th NFCAAA Summer Seminar (talks, contests, sponsored by the Syracuse Astronomical Society), Syracuse, New York. Contact: Frank Rioux, Summer Seminar, Syracuse Astronomical Society, 1115 East Colvin Street, Syracuse, NY 13210. Phone: (315) 455-1003.

July 27-30
ALCON, the 1988 Astronomical League Convention jointly sponsored by the Association of Lunar and Planetary Observers, Iowa Western Community College, near Omaha/Council Bluffs, Nebraska. Contact: George E. Allen, 3390 South 130th Street, Omaha, NE 68144. Phone: (402) 333-1097.

July 27-30
The Teaching of Astronomy (colloquium sponsored by the International Astronomical Union), Williams College, Williamstown, Massachusetts. Contact: Jay M. Pasachoff, Department of Astronomy, Williams College, Williamstown, MA 01267.

August 5-6
Starfest '88 (sponsored by the North York Astronomical Association), River Place Campground, north of Mount Forest, Ontario. Contact: North York Astronomical Association, 16 Beaufield Avenue, Toronto, Ontario, Canada M4G 3R3.

August 10-14
5th Annual Mount Kobau Star Party (observing, telescope-making and astrophotography contests, speakers), Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

August 12-15
Nova East '88 (sponsored by Royal Astronomical Society of Canada — Halifax and Saint John centres), Fundy National Park, New Brunswick. Contact: Royal Astronomical Society of Canada — Halifax Centre, 1747 Summer Street, Halifax, Nova Scotia, Canada B3A 4J8.

August 13
2nd Astronomy Rendezvous and Conference — 1988 (sponsored by the Twin City Amateur Astronomers), Illinois State University, Normal, Illinois. Contact: Kevin Brown, ARC '88 Chairman, 813 West Oakland Avenue, Bloomington, IL 61701. Phone: (309) 827-6790.

August 13
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.

August 19-21
Alberta Star Party (hosted by the Royal Astronomical Society of Canada — Edmonton Centre), Dinosaur Province Park, Alberta. Contact: Royal Astronomical Society of Canada — Edmonton Centre, 4203-10613 Avenue, Edmonton, Alberta, Canada T6A 1K7.

August 27-28
Annual Convention of the Astronomical Association of Northern California, Lawrence Hall of Science, Berkeley, California. Contact: Don Stone, AANC President, 731 Camino Ricardo, Moraga, CA 94556-1328. Phone: (415) 376-3007 (evenings).

September 16-18
Astronomer's Conjunction (camping, observing, swap table), Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Road, Springfield, MA 01118.

AstroCalendar notices must be submitted at least four months in advance of the date of the event.

When contacting organizations that are sponsoring events, enclose a self-addressed, stamped, legal-size envelope for their response.

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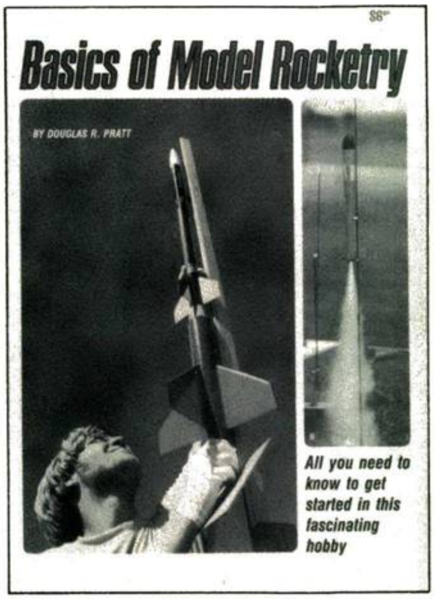
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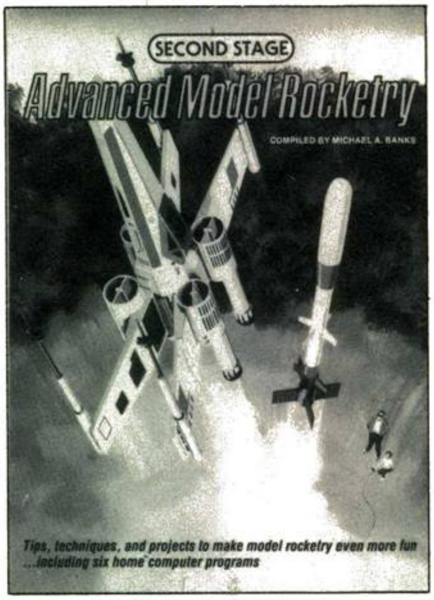
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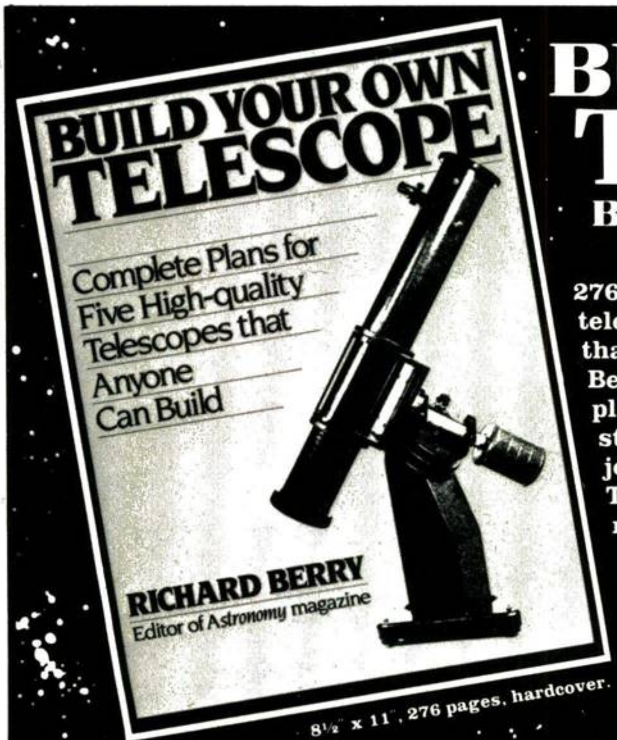
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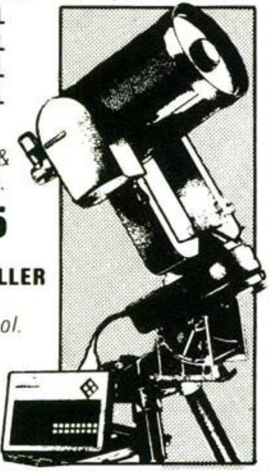

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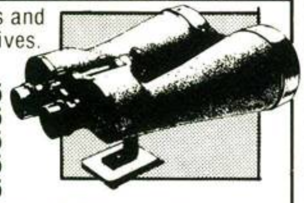

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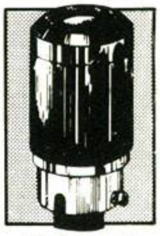

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AST-058

Gazer's Gazette

Seeing Double

by Phil Harrington

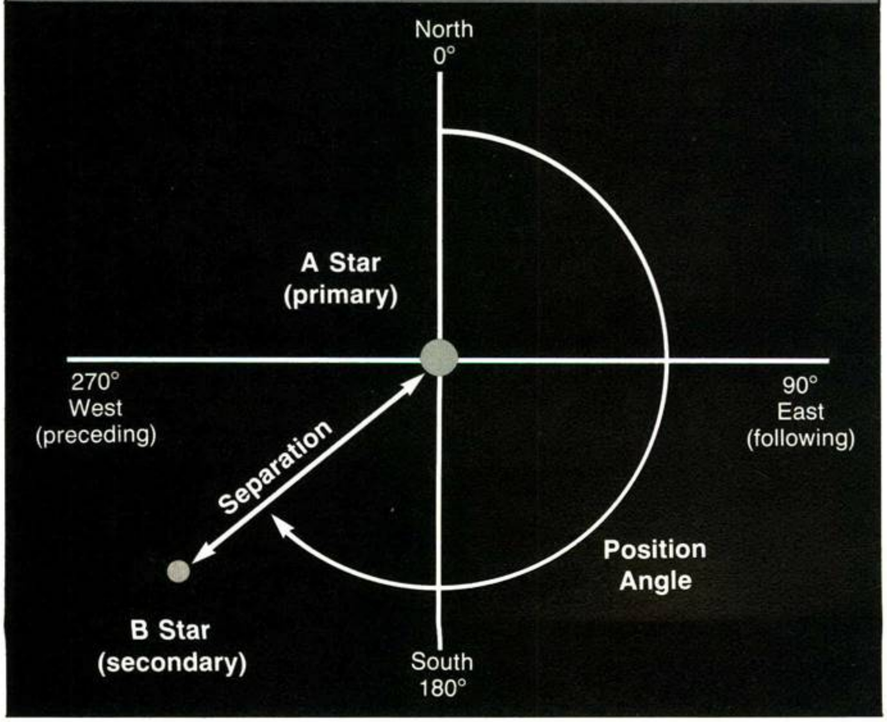
Mention "deep-sky observing" and most amateurs think of sparkling star clusters, rifts of nebulosity, or dim galaxies, discernible only in dark, transparent skies. But one group of deep-sky objects — double stars — can be enjoyed under the Full Moon or from city and country skies.

Nearly half of all the stars in the sky are members of double or multiple star systems. What makes binary stars so appealing — aside from the sheer "kick" of seeing a single star split into a close pair — is that every double is unique. In some you'll see component stars nearly equal in brightness, while in others you'll see striking contrasts in brightness. In some the components shine pure white, while in others the stars glimmer in distinctive colors — rose, pink, yellow, pale blue, cerulean, and violet — made stronger or more apparent by the proximity of the stars.

Double stars may be so widely separated that you can see them with the naked eye or so close that they are just barely resolved into two stars with the largest telescopes. Astronomers measure the separation of doubles in arcseconds. An arcsecond is a very small angle, 1/60th of an arcminute, which, in turn, is 1/60th of a degree. (For comparison, the Moon spans an angle of 1,800 arcseconds.)

Two different kinds of double stars are visible: optical doubles and visual binaries. Optical doubles are impostors. They look double only because both stars happen to lie on nearly the same line of sight from Earth. But while they appear close together in our sky, they're at greatly different distances and have no physical connection.

How Astronomers Measure Double Stars



Alcor and Mizar, the naked-eye double in the handle of the Big Dipper, is the best-known optical double. Before you write off Mizar, however, remember that Mizar itself happens to be the other kind of double: a visual binary.

In visual binaries the stars actually orbit each other in space. The orbital periods of visual binaries vary from tens of thousands of years to just a few years. Most visual binaries have long orbital periods; in fact, the periods are so long in many cases that the stars haven't moved since their discovery. (Of course, if we wait a few hundred years more, their movement will be plain to see.)

The brightest star in a binary system is called A, while the fainter secondary is called B. For example, the components of the double star Sirius are called Sirius A and Sirius B. If there are other, fainter components, they're labeled C, D, and so on.

Besides the brightnesses and separation of the stars, we can also specify the orientation of double stars. The p.a., or position angle, is the angle between the primary and secondary stars relative to north. If the B star is due north of the A star, then its p.a. is 0 degrees. If the companion is due east, then the p.a. is 90 degrees. A p.a. of 180 degrees places the companion due south, while a p.a. of 270 degrees indicates that the companion is due west of the primary.

To observe a double star with your telescope, first locate the star at low power. If it's a wide double — one with a separation greater than 4 arcseconds — you'll be able to see two stars at 60x or so. If the double is a close one, switch to a high-power eyepiece. The highest useful magnification is about fifty times the aperture of your telescope in inches; that is, around 400x for an 8-inch telescope.

As you observe a double, look for color differences between the stars. The components of most binaries, even ones that look alike at first glance, display some color contrast. If you don't see color with

How Close a Double Can Your Telescope Split?

Aperture of Telescope (inches)	Closest Double (arcseconds)
1	4.56
2	2.28
3	1.52
4.25	1.08
6	0.76
8	0.57
10	0.46
12.5	0.36
16	0.29
20	0.23

the stars in focus, try putting the stars just slightly out of focus — this can make the hues of the more subtle doubles more obvious. The table at right lists the best-known double stars for North Hemisphere observers.

The closer a stellar pair, the larger the telescope you'll need to resolve it. Because bigger telescopes produce smaller star images, bigger telescopes can resolve, or show as two, closer pairs of stars. If your telescope cannot resolve a double star, you'll see only one star or an elongated stellar image that isn't clearly split.

During the mid-1800s an astronomer named William Dawes experimentally determined that a telescope of *x* inches aperture should just be able to resolve a pair of equally bright 6th-magnitude stars separated by (4.56/*x*) arcseconds under good seeing conditions. This is called the Dawes Limit.

To split doubles near the Dawes Limit, the components of a double star must be about 6th magnitude, nearly equal in brightness, and the optics in your telescope must be excellent. Above all else, though, the atmosphere must be steady. Typically the best nights for doubles aren't crystal clear. The steadiest conditions usually occur when skies are slightly hazy. The lower table on this page lists double stars that are especially good for testing your telescope and skill as an observer.

Doubles found in the 1800s by Wilhelm Struve bear the uppercase Greek letter sigma, Σ; those his son Otto Struve discovered are labeled OΣ. Stars listed in the *New General Catalog of Double Stars,* compiled in 1932 by Robert G. Aitken, carry the prefix "ADS" plus a number. Aitken's catalog includes nearly all the stars the Struves discovered, so many doubles go by more than one name.

You can spend many enjoyable hours at the eyepiece splitting double stars. These stars test both the quality of your telescope's optics and the acuity of your eyesight and are fascinating objects in their own right.

Some of the Finest Double Stars

ADS No.	Name	R.A. (1950.0)	Dec. (1950.0)	Mags.	Sep.	P.A.
671	Eta Cas	0h46.1m	+57°33′	3.5, 7.5	12.0″	307
1507	Gamma Ari	1h50.8m	+19°03′	4.6, 4.7	7.8″	0
1697	Iota Tri	2h09.5m	+30°04′	5.3, 6.9	3.9″	71
1860	Iota Cas	2h24.9m	+67°11′	4.6, 6.9	2.4″	234
2616	7 Tau	3h31.5m	+24°18′	6.6, 6.7	0.6″	6
2850	32 Eri	3h51.8m	−03°06′	4.7, 6.2	6.7″	347
3823	Beta Ori	5h12.1m	−08°15′	0.2, 6.7	9.2″	206
4241	Sigma Ori	5h36.2m	−02°38′	3.8, 6.6	12.9″	84
5107	Beta Mon	6h24.4m	−07°00′	4.6, 5.1	7.2″	132
5423	Alpha CMa	6h43.0m	−16°39′	−1.5, 8.5	6″	15
6175	Alpha Gem	7h31.4m	+32°00′	1.9, 2.9	2.2″	95
6988	Iota Cnc	8h43.7m	+28°57′	4.0, 6.6	30.4″	307
7724	Gamma Leo	10h17.2m	+20°06′	2.2, 3.5	4.3″	123
8600	24 Com	12h32.6m	+18°39′	5.2, 6.8	20.2″	271
8630	Gamma Vir	12h39.1m	−01°11′	3.5, 3.5	3.9″	297
8706	Alpha CVn	12h53.7m	38°35′	2.9, 5.5	19.4″	229
8891	Zeta UMa	13h21.9m	+55°11′	2.3, 4.0	14.4″	151
9338	Pi Boo	14h38.4m	+16°38′	4.9, 5.8	5.7″	108
9372	Epsilon Boo	14h42.8m	+27°17′	2.5, 5.0	2.8″	339
9737	Zeta CrB	15h37.5m	+36°48′	5.1, 6.0	6.3″	305
9913	Beta Sco	16h02.5m	−19°40′	2.7, 4.9	13.6″	21
10417	36 Oph	17h12.3m	−26°32′	5.1, 5.1	4.6″	155
10418	Alpha Her	17h12.4m	+14°27′	3.2, 5.4	4.7″	107
10993	95 Her	17h59.4m	+21°36′	5.1, 5.2	6.5″	258
12540	Beta Cyg	19h28.7m	+27°52′	3.2, 5.4	34.4″	54
12880	Delta Cyg	19h44.4m	+45°04′	2.9, 6.3	2.4″	230
12962	Pi Aql	19h47.7m	+11°45′	6.0, 6.8	1.4″	108
14279	Gamma Del	20h44.3m	−15°57′	4.3, 5.2	9.8″	268
14636	61 Cyg	21h05.5m	+38°34′	5.2, 6.0	29.7″	147
15971	Zeta Aqr	22h26.2m	−00°17′	4.3, 4.5	1.8″	226

Selected Double Stars for Resolution Tests

1457	1 Ari	1h50.1m	+22°17′	6.2, 7.4	3.2″	166
15971	Zeta Aqr	22h28.8m	−00°02′	4.4, 4.6	1.6″	232
755	36 And	0h55.0m	+23°38′	6.0, 6.4	0.7″	292
16836	72 Peg	23h34.0m	+31°20′	5.6, 5.7	0.5″	252
—	45 And	1h11.2m	+37°43′	6.6, 6.6	0.4″	280
14773	Delta Equ	21h14.5m	+10°01′	5.3, 5.4	0.3″	22
15902	51 Aqr	22h24.1m	−04°51′	6.6, 6.6	0.2″	301
4068	118 Tau	5h29.3m	+25°09′	5.8, 6.6	4.8″	204
4002	Eta Ori	5h24.5m	−02°24′	3.7, 5.1	1.6″	80
4208	Σ 749 (Tau)	5h37.1m	+26°55′	6.4, 6.5	1.0″	333
3711	14 Ori	5h07.9m	+08°30′	5.8, 6.5	0.7″	38
—	31 Tau	3h52.0m	+06°32′	6.4, 6.5	0.4″	207
3182	66 Tau	4h23.9m	+09°28′	5.8, 5.9	0.1″	211
6815	Phi^{2} Cnc	8h26.8m	+26°56′	6.3, 6.3	5.1″	218
8119	Xi UMa	11h18.5m	+31°13′	4.3, 4.8	2.3″	97
9343	Zeta Boo	14h14.1m	+13°44′	4.5, 4.6	1.0″	125
8804	Alpha Com	13h10.0m	+17°32′	5.1, 5.1	0.6″	15
8987	Beta 612 (Boo)	13h39.6m	+10°45′	6.3, 6.3	0.3″	240
9301	A 570 (Boo)	14h32.3m	+26°41′	6.5, 6.7	0.2″	319
11635	Epsilon^{1} Lyr	18h44.3m	+39°40′	5.2, 6.1	2.7″	354
11635	Epsilon^{2} Lyr	18h44.3m	+39°40′	5.2, 5.5	2.4″	89
10345	Mu Dra	17h05.3m	+54°28′	5.8, 5.8	1.9″	47
13277	16 Vul	20h01.8m	+24°56′	5.9, 6.3	0.8″	118
11479	OΣ 359 (Her)	18h35.5m	+23°36′	6.3, 6.5	0.6″	191
11111	73 Oph	18h09.2m	−26°07′	6.1, 7.0	0.4″	304
11344	OΣ 351 (Dra) A, C	18h25.3m	+48°46′	7.7, 8.2	0.5″	22
11344	Hu 66 (Dra) A, B	18h25.3m	+48°46′	7.9, 8.1	0.3″	265

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Shown: 2120/LX3 MCOG

Includes Hand Control Unit!

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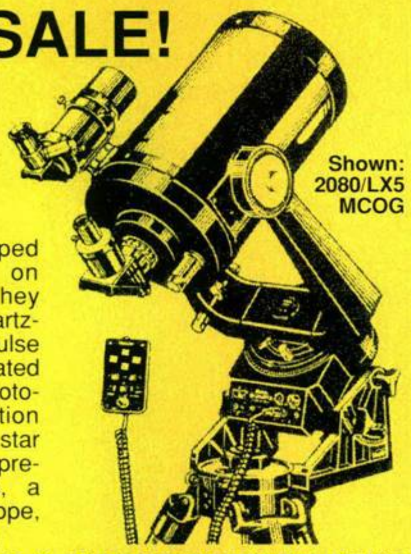

Shown: 2080/LX5 MCOG

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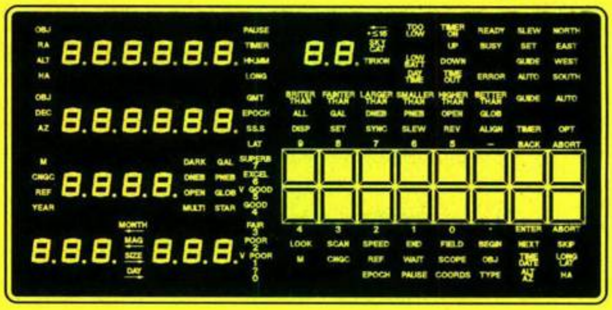
CELESTRON CompuStar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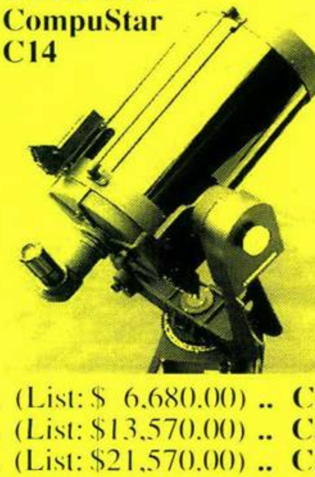

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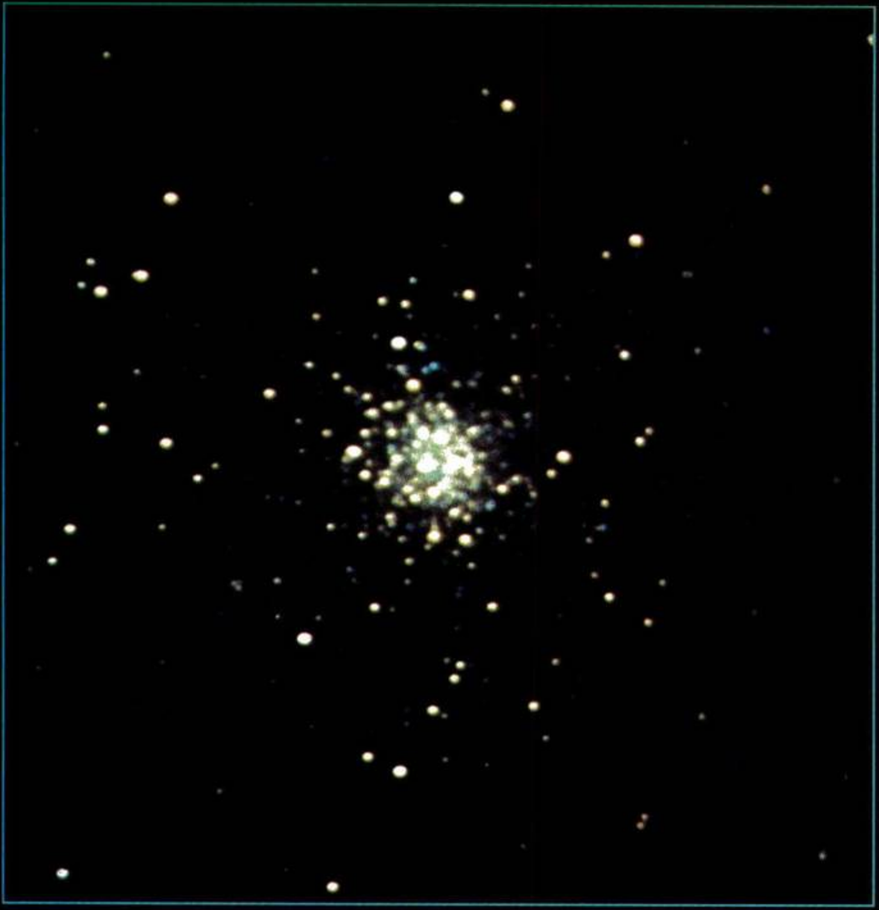
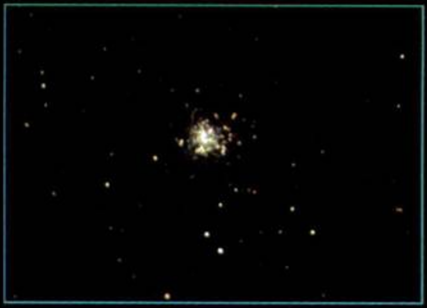
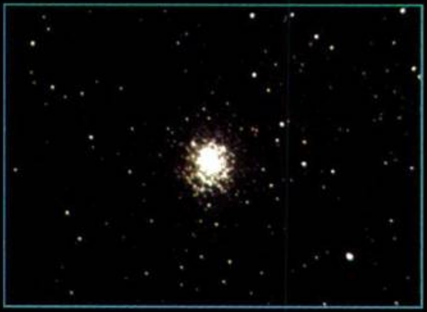
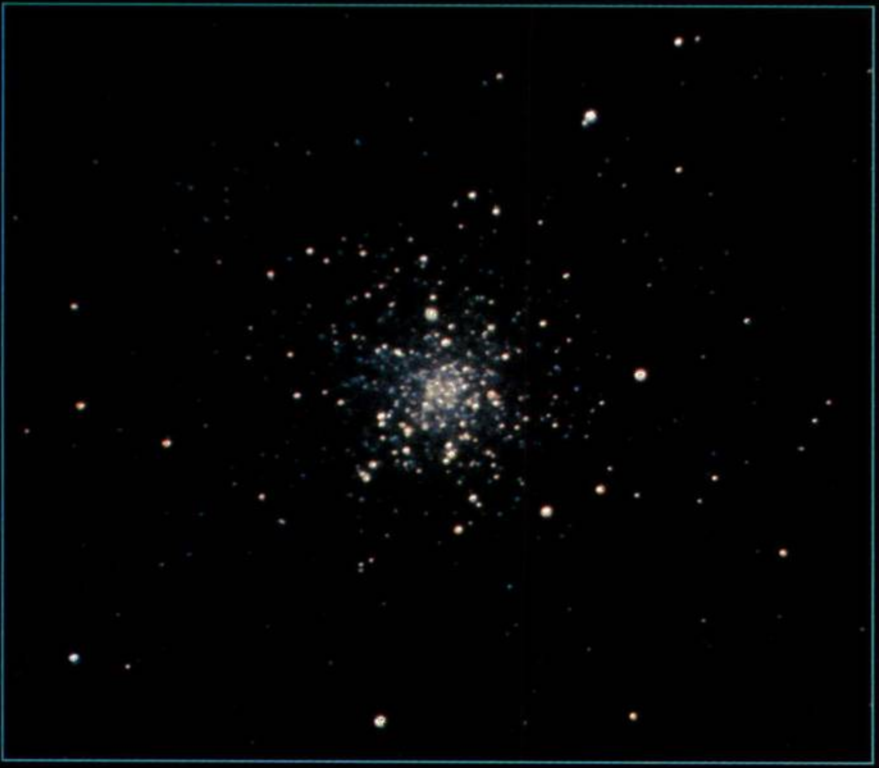


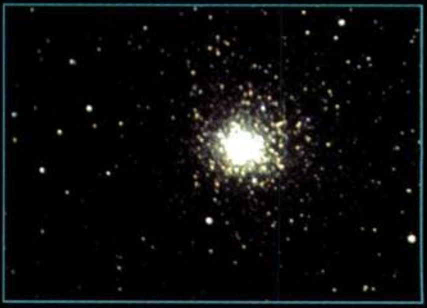


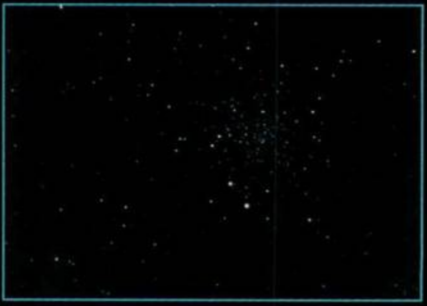


Top: In backyard telescopes globular cluster M9 has a bright core surrounded by a diffuse halo, the light from thousands of unresolved stars. Photo by Ben Mayer.

Above: M19 has a feature not as easily visible in any other globular cluster: M19 appears clearly oval even at low power. Photo by Ben Mayer.







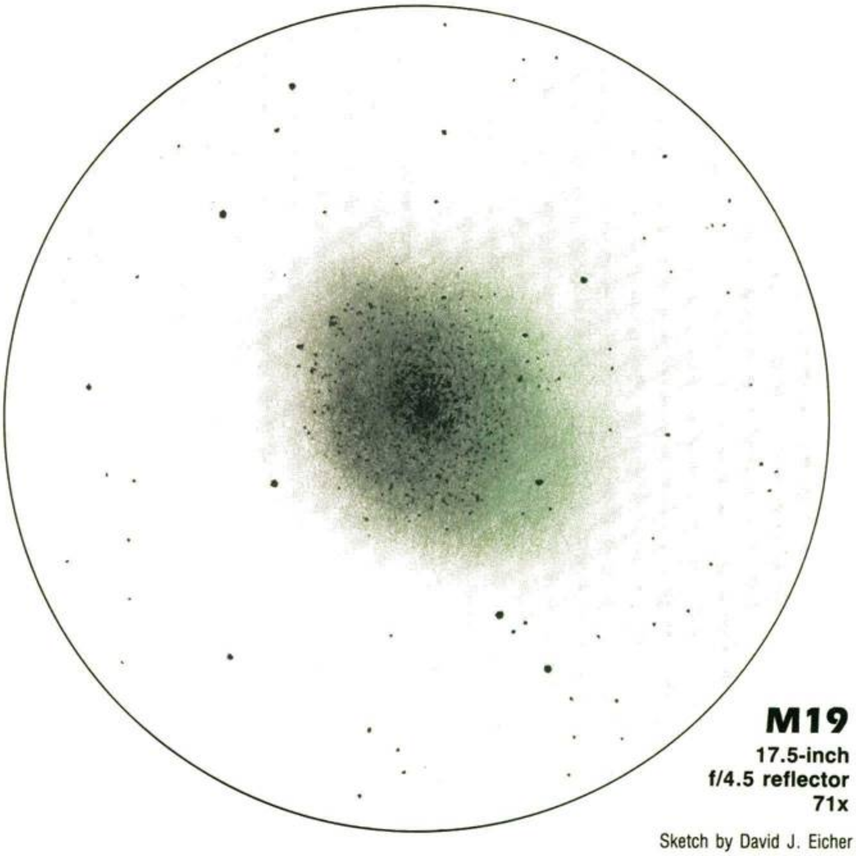
Top: Unlike the other bright globulars in Ophiuchus, M62 is highly condensed and difficult to resolve into stars. Can you resolve the cluster's outer edges with an 8-inch telescope at high power? Photo by Ben Mayer.

Above: The opposite of M62, NGC 6366 is so spread out it is difficult to see at all. The cluster's sprinkling of faint stars may be visible on dark nights in a 10-inch scope. Photo by Martin C. Germano.

Top: Because of its location toward the galactic center, Ophiuchus contains one sixth of all globular clusters in the sky. One of the constellation's three brightest globulars is M12, a loose cluster resolvable in an 8-inch scope. Photo by Bill Iburg.

Above: As bright as M12 and slightly larger is M10, a cluster lying 3.4° southeast of M12. Because of their proximity, the two clusters appear to be twins, but they actually lie far apart in space. Photo by Ben Mayer.

A Golden Opportunity for Globular Clusters



M19
17.5-inch
f/4.5 reflector
71x

Sketch by David J. Eicher

Summer provides the best opportunity for viewing globular clusters. In June as evening twilight fades into blackness, galaxies in Virgo are setting in the west and the Milky Way is rising in the east. High in the southeast lies Ophiuchus, a constellation that remains visible for several hours during the brief nights of summer. Ophiuchus is prime globular cluster territory: the constellation contains one sixth of the known globular clusters in the Milky Way.

When you look toward Ophiuchus, you're looking toward the northwestern edge of our Galaxy's central bulge. Aside from nearby foreground stars, this area of sky is filled with a blanket of gas and dust and countless old yellow and red stars lying above the plane of the Galaxy. Galaxies are too distant and faint to shine through the obscuring blanket of gas and dust, but globular clusters are near enough and intrinsically bright enough to show up easily. The twenty-four globulars in Ophiuchus offer you a chance to see the differences and similarities typical of Milky Way globulars.

Among the brightest globulars in Ophiuchus are neighbors **M10** (NGC 6254) and **M12** (NGC 6218), each just beyond naked-eye visibility. Find M10 by aiming your finder scope at the wide naked-eye pair of stars Delta (δ) and Epsilon (ε) Ophiuchi, and slowly move the telescope 10° due east. Now check your finder: you should see a solitary 5th-magnitude ruddy star (30 Ophiuchi) and the fuzzy glow of M10 about 1° west of the star. M12 lies just 3.4° northwest of M10.

M10 and M12 are remarkably similar in size and brightness. Each glows at magnitude 6.6. M12 measures 14.5′ across and M10 spans 15.1′. However, M10 and M12 appear similar and close in the sky only by coincidence: they are actually separated by 1.1 kiloparsecs. If you were an observer on a planet in one of these clusters, the other cluster would appear as a magnificent 2nd-magnitude object easily resolved into hundreds of stars.

The clusters are relatively easy to resolve into stars in our sky as well. A 6-inch telescope at high power shows M10 as a bright ball of light surrounded by a faint milky haze that contains several stars. A 10-inch telescope improves the view by resolving several dozen stars near the cluster's edges and by revealing a bright, tiny core. Large backyard telescopes in the 16-inch class reveal that M10 is a relatively "loose" globular because they resolve dozens of stars across the cluster's face.

M12 appears the same as its neighbor does. Although it is even looser than M10, M12 is slightly more challenging to resolve into stars because it contains fewer bright stars. However, on a dark night a 6-inch telescope shows a large, nebulous glow with an overall mottled appearance and a handful of resolved stars at the cluster's edges. A 14-inch or 16-inch telescope shows streams of stars radiating from M12's center, suggesting a pinwheel. This attribute was first noticed by the astronomer Lord Rosse in the mid-nineteenth century. Another attractive aspect of observing M12 is a bright red field star just off the cluster's southern edge.

In stark contrast to M10 and M12, **Palomar 15** is one of the most challenging globular clusters in the sky. Palomar 15 lies 3° north of M10 and 3° northeast of M12, forming an equilateral triangle with the bright clusters. An intrinsically large and bright cluster, Palomar 15 lies at the whopping distance of 70 kiloparsecs — twice the diameter of the Milky Way's disk! The cluster glows feebly at magnitude 14.2 and spans 4.2′, which give it a very low surface brightness. Palomar 15 can just be glimpsed with an 18-inch or 20-inch telescope. If you don't have a large telescope, save your attempts to view this object for a star party. Or, better yet, try to photograph the cluster — you may well succeed in recording it as a small, circular haze.

Now move your telescope 10° east and slightly north of M10 and you'll find another Messier object, **M14** (NGC 6402). This cluster glows at magnitude 7.6 and covers 11.7′ but is not as impressive as M10 or M12 because its stars are much fainter. A 4-inch telescope shows a 3′-diameter spot of hazy light, and an 8-inch scope fails to do much better. On a dark night a 12-inch telescope resolves the edges of M14 into a few scattered stars, but the core remains a nebulous disk.

Three degrees southwest of M14 lies the 5th-magnitude star 47 Ophiuchi. Within the same low-power field of view just 30′ to the east is the faint globular **NGC 6366**. This cluster glows at 10th magnitude and covers 8′ of sky. NGC 6366 is a sparse

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Martin C. Germano

Globular Cluster M14

group with its light spread out enough to yield a low surface brightness. In an 8-inch telescope NGC 6366 appears like a faint, uniformly illuminated circular patch. A 12-inch telescope shows a few faint individual stars in this cluster. If you're having trouble spotting NGC 6366, switch to moderately high power and nudge 47 Ophiuchi outside the field of view.

NGC 6517 is located midway between 3rd-magnitude Nu (ν) Ophiuchi and the 5th-magnitude double star Tau (τ) Ophiuchi. Glowing at 10th magnitude and measuring 4.3′ across, NGC 6517 appears small, faint, and condensed in backyard telescopes. Its stars are densely packed, so you'll have a difficult time resolving them.

NGC 6426 lies in northeastern Ophiuchus, 1.5° south of Beta Ophiuchi and 3° south of the large, naked-eye open cluster IC 4665. More challenging than NGC 6517, NGC 6426 glows delicately at magnitude 11.2 and spans a mere 3.2′. The light from this distant globular is heavily obscured by dust in the galactic disk, which causes the cluster to appear like a featureless, 2′-diameter disk of gray light even in large backyard telescopes.

Southern Ophiuchus holds an even larger batch of bright globular clusters. **M107** (NGC 6171) is located 2.8° southwest of the 3rd-magnitude star Zeta (ζ) Ophiuchi. An 8th-magnitude object, M107 is the easiest globular to resolve in the constellation. An 8-inch telescope shows a mottled halo of light peppered with points of light around a bright, ball-like core. A 12-inch scope resolves the cluster across the face and shows many stars arranged in clumps and lines.

Two-and-a-half degrees north-northwest of Xi (ξ) Ophiuchi is another 8th-magnitude cluster, **M9** (NGC 6333). In a small telescope this object appears like a 5′-diameter disk of gray-green light. A 10-inch telescope resolves this cluster's edges on a crisp, dark night. M9 is one of the closest globular clusters to the center of the Galaxy, lying about 2 kiloparsecs away (and 6.9 kiloparsecs away from us). As you observe M9, see if you can detect the cloud of dark nebulosity, Barnard 64, that partially obscures the cluster's southwestern side. Two smaller clusters lie in the M9 area. **NGC 6356** is 1.3° northeast of M9 and visible as a large disk of light without resolution. **NGC 6342** is a small cluster immediately south of a 7th-magnitude double star that lies 1° southeast of M9. NGC 6342 is a small, dim, highly compressed cluster.

One of the brightest globulars in Ophiuchus is **M62** (NGC 6266), an object lying practically on the constellation's border with Scorpius. Although it lies in a rich field of stars, there are no bright landmark stars near the cluster. The best way to find M62 is to start at the optical double 45 Ophiuchi and slowly move your telescope 5.5° due west. M62 shines at magnitude 6.6 and measures 14.1′ across, which makes it easily visible in a 4-inch scope. The cluster's most curious feature, visible in a 6-inch instrument, is its distinctly asymmetrical shape. A 10-inch telescope shows mottling around the cluster's edges but fails to resolve it into stars. A 16-inch telescope at high power does a nice job of showing the cluster's brightest individual members.

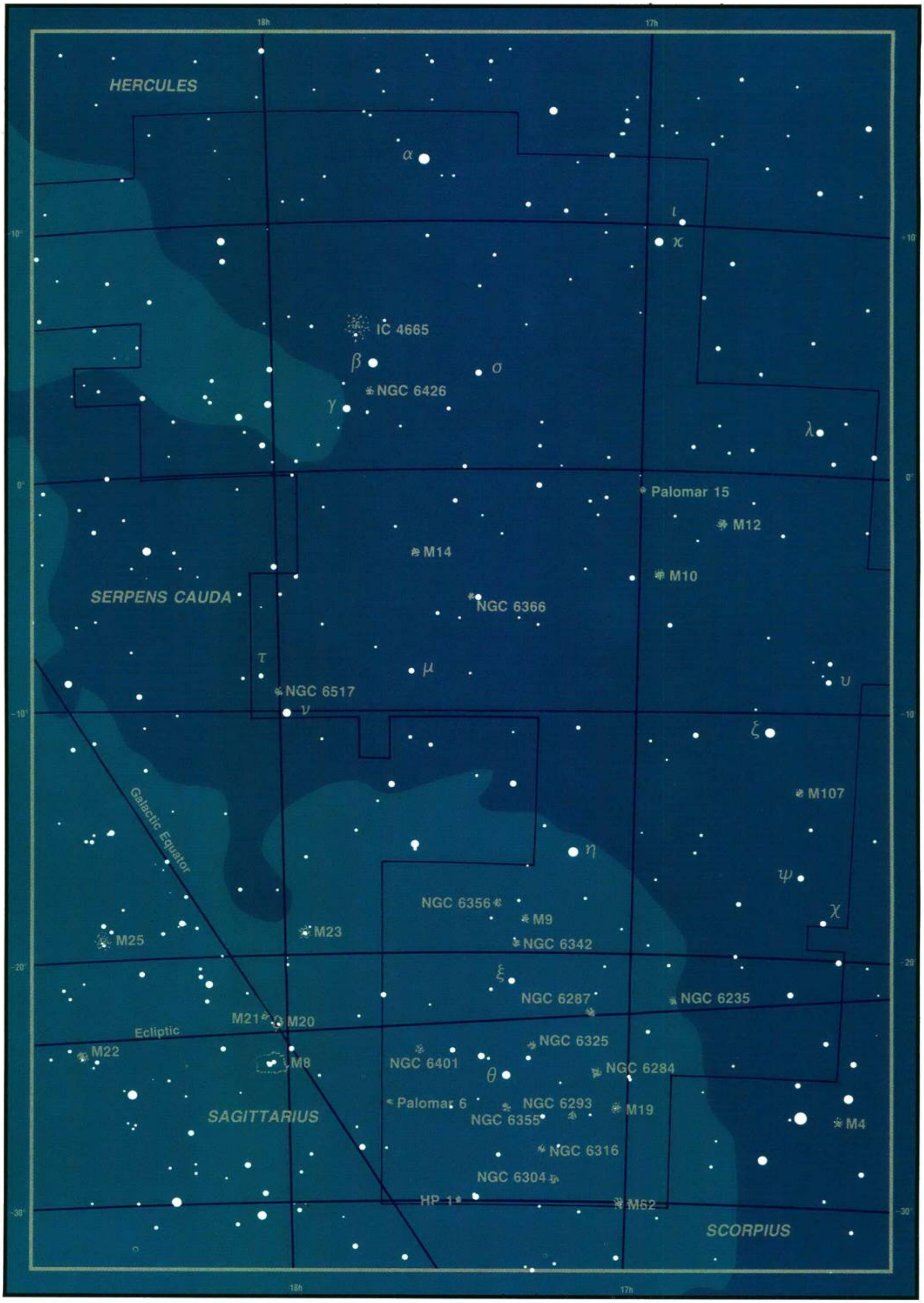
Four degrees north of M62 is the bright globular **M19** (NGC 6273). Although M19 lies at a distance of 10.6 kiloparsecs, it has a magnitude of 7.2 and is one of the constellation's nicest sights. Lying in a rich, starry field, M19 is easily visible in a 4-inch scope. It is possibly the most oval globular cluster in the sky. This flattening of one side, caused by the cluster's rotation, can be seen plainly in a 6-inch telescope. Moderately loose, M19's brightest stars are visible in an 8-inch telescope on a dark, transparent night.

— David J. Eicher

Globular Clusters in Ophiuchus

Object	M#	R.A. (2000)	Dec.	Mag.	Size	Concentration Class	Distance
NGC 6171	M107	16h32.5m	−13°03′	8.1	10.0′	10	5.9 kpc
NGC 6218	M12	16h47.2m	−1°57′	6.6	14.5′	9	5.5 kpc
NGC 6235		16h53.4m	−22°11′	10.2:	5.0′	10	10: kpc
NGC 6254	M10	16h57.1m	−4°06′	6.6	15.1′	7	4.4 kpc
Palomar 15		16h59.9m	−0°32′	14.2	4.2′	—	70: kpc
NGC 6266	M62	17h01.2m	−30°17′	6.6	14.1′	4	6.0 kpc
NGC 6273	M19	17h02.6m	−26°16′	7.2	13.5′	8	10.6 kpc
NGC 6284		17h04.5m	−24°46′	9.0:	5.6′	9	10: kpc
NGC 6287		17h05.2m	−22°42′	9.2:	5.1′	7	9: kpc
NGC 6293		17h10.2m	−26°35′	8.2:	7.9′	4	7.3: kpc
NGC 6304		17h14.5m	−29°28′	8.4	6.8′	6	5.4 kpc
NGC 6316		17h16.6m	−28°08′	9.0:	4.9′	3	12: kpc
NGC 6325		17h18.0m	−23°46′	10.7	4.3′	4	19.4 kpc
NGC 6333	M9	17h19.2m	−18°31′	7.9:	9.3′	8	6.9: kpc
NGC 6342		17h21.2m	−19°35′	9.9:	3.0′	4	15: kpc
NGC 6356		17h23.6m	−17°49′	8.4	7.2′	2	17.2 kpc
NGC 6355		17h24.0m	−26°21′	9.6:	5.0′	—	6.8: kpc
NGC 6366		17h27.7m	−5°05′	10.0:	8.3′	11	4.0: kpc
HP 1		17h31.1m	−29°59′	—	2.9′	—	—
NGC 6402	M14	17h37.6m	−3°15′	7.6	11.7′	—	10.2 kpc
NGC 6401		17h38.6m	−23°55′	9.5:	5.6′	8	6.8: kpc
Palomar 6		17h43.7m	−26°13′	13.6	7.2′	11	2.9: kpc
NGC 6426		17h44.9m	−3°00′	11.2	3.2′	9	16.0 kpc
NGC 6517		18h01.8m	−8°58′	10.3:	4.3′	4	7.8: kpc

: denotes uncertainty. Concentration class ranges from 1 to 12; 1 represents the most concentrated and 12 the least concentrated.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NGC 6426
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Palomar 15
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M107
Galactic Equator
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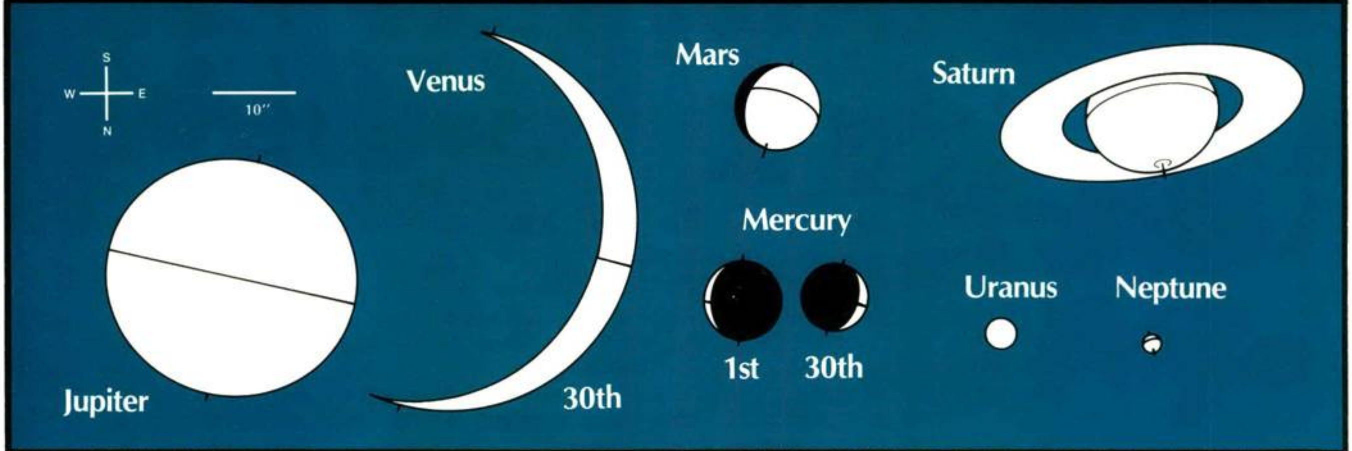
ψ
χ
NGC 6356
M9
M25
M23
NGC 6342
-20°
ξ
NGC 6287
NGC 6235
M21
M20
Ecliptic
M22
NGC 6325
M8
NGC 6401
θ
NGC 6284
Palomar 6
NGC 6293
M19
SAGITTARIUS
NGC 6355
M4
NGC 6316
NGC 6304
HP 1
M62
-30°
SCORPIUS
18h
17h

Planetary Data

June 1988


S
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E
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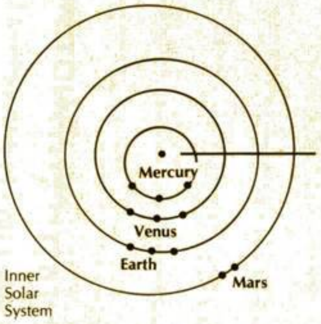
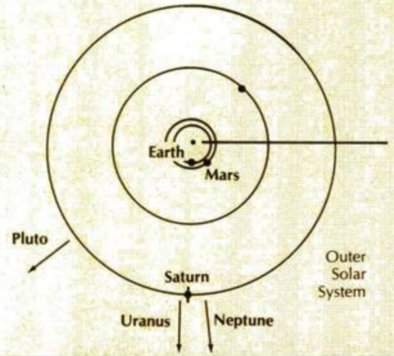
10″
Venus
30th
Mars
Saturn
Mercury
1st
30th
Uranus
Neptune
Jupiter

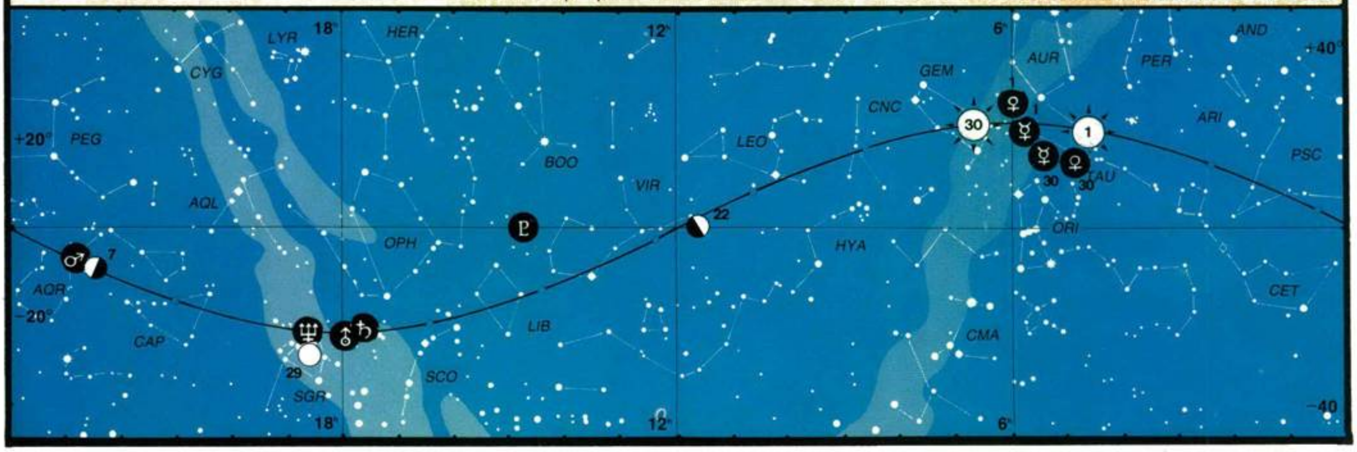
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.6′	—	1.014	—	—	70°43.6′	4h37.2m	22°04.8′
		15	−26.7	31.5′	—	1.016	—	—	84°07.1′	5h35.1m	23°19.2′
		30	−26.7	31.5′	—	1.017	—	—	98°25.8′	6h37.4m	23°09.9′
Mercury	☿	1	2.4	10.8″	10.9%	0.620	0.452	228°26.8′	86°43.1′	5h46.7m	23°23.1′
		15	5.0	12.1″	8%	0.555	0.465	267°26.8′	81°33.7′	5h24.0m	19°27.5′
		30	1.4	9.4″	21%	0.715	0.419	312°49.5′	79°34.1′	5h15.0m	18°56.4′
Venus	♀	1	−4.2	53.7″	5%	0.311	0.725	243°08.9′	88°28.3′	5h54.8m	25°16.8′
		15	−3.7	57.5″	3%	0.289	0.727	265°22.7′	81°08.6′	5h21.7m	21°50.7′
		30	−4.3	50.3″	11%	0.331	0.728	289°07.0′	74°49.1′	4h54.7m	18°33.1′
Mars	♂	10	−0.4	11.0″	85%	0.851	1.409	296°03.5′	341°46.5′	22h57.2m	−9°44.3′
		20	−0.6	11.9″	85%	0.786	1.402	302°11.5′	347°39.4′	23h19.7m	−7°46.2′
Jupiter	♃	15	−2.0	33.8″	100%	5.824	4.985	46°34.3′	52°49.6′	3h22.7m	17°36.6′
Saturn	♄	15	0.0	18.3″	100%	9.032	10.044	269°05.4′	269°48.4′	17h59.2m	−22°17.8′
Uranus	⛢	15	5.5	3.8″	100%	18.267	19.279	268°59.4′	269°25.8′	17h57.5m	−23°39.2′
Neptune	♆	15	7.9	2.3″	100%	29.243	30.225	278°43.0′	279°22.3′	18h40.6m	−22°07.1′
Pluto	♇	15	13.7	0.1″	100%	28.956	29.665	221°30.3′	220°18.2′	14h51.7m	0°44.7′


Mercury
Venus
Earth
Mars
Inner Solar System


Earth
Mars
Pluto
Saturn
Uranus
Neptune
Outer Solar System

Moon Data

Last Quarter	June 7 at 6h21m
New Moon	June 14 at 9h14m
First Quarter	June 22 at 10h23m
Full Moon	June 29 at 19h46m
Last Quarter	July 6 at 11h36m
New Moon	July 13 at 21h53m
Perigee: June 4 at 23h45m	368,484 km
Apogee: June 20 at 8h12m	404,542 km


LYR
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6h
AUR
AND
+40°
CYG
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CNC
+20°
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LEO
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BOO
PSC
VIR
TAU
AQL
22
HYA
ORI
OPH
7
AQR
CET
−20°
LIB
CMA
CAP
29
SCO
SGR
18h
12h
6h
−40
30
1
30
30

Twisting through rich starfields like glowing strands of rope, the Veil supernova remnant is faintly visible to backyard observers on summer nights. NGC 6979, a trianglar wisp of nebulosity, lies between the supernova remnant's two brightest sections. Jack Newton used a 20-inch f/5 telescope, chilled Fujichrome 400 film, and a light-pollution-reduction filter for the 30-minute exposure.

Planets

Mercury

On the first few evenings of June Mercury is visible a few degrees above the northwest horizon. It also lies at about the same elevation in the northeast on the last few mornings of June. (In the evening Mercury lies right below Venus; in the morning it lies to Venus' lower left.) Between the two appearances, Mercury passes through inferior conjunction on June 13, and is therefore out of sight most of the month.

On June 1, magnitude 2.4 Mercury is a thin crescent about 11″ across and only 11 percent illuminated. On the 30th, it will be brighter (1.4 magnitude), 9″ in diameter, and 21 percent illuminated. Unfortunately telescopic views at its extremely low elevation will be dominated by bad seeing. The morning apparition next month will offer better viewing opportunities.

Venus

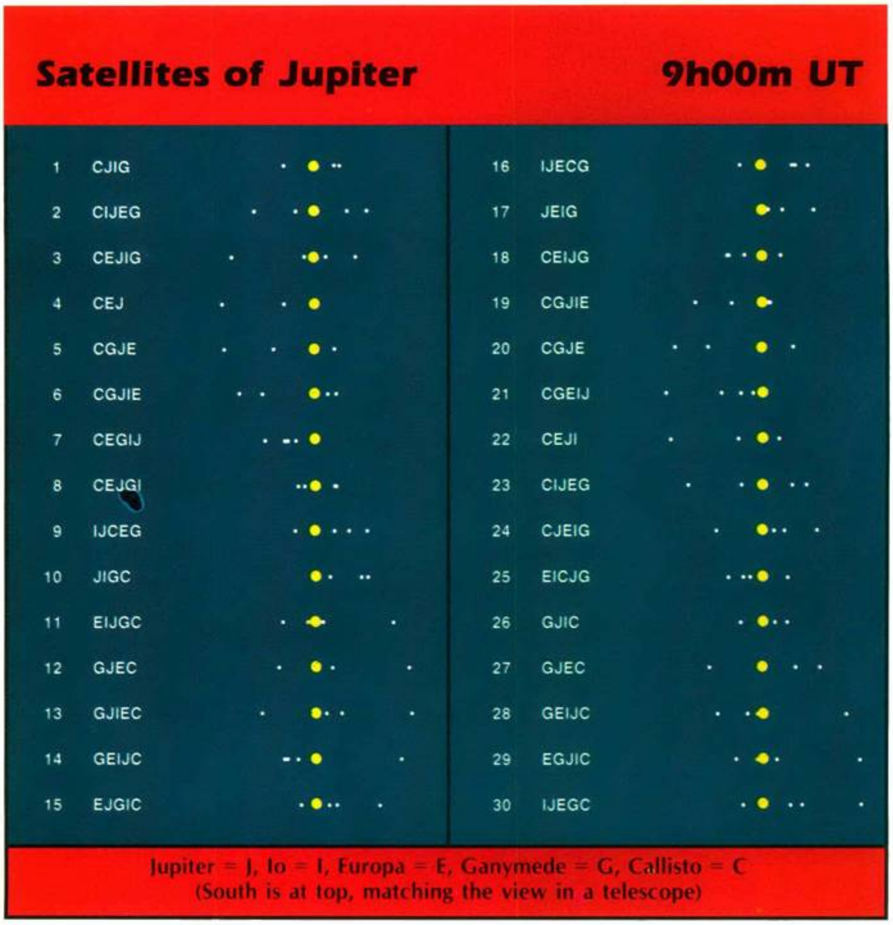
Venus' course this month parallels that of Mercury. Venus will even pass through inferior conjunction just four hours ahead of Mercury on June 13. Brighter than magnitude −4, Venus is easy to locate even when it's low in the sky.

As with Mercury, the low elevation of Venus hampers telescopic viewing. But don't let that prevent you from viewing Venus this month. As it nears inferior conjunction, Venus grows in size to an amazing degree, while its illuminated crescent shrinks to a sliver. This is a breathtaking sight you can see only at twenty-month intervals. Don't miss it!

Mars

Mars is attracting a lot of interest as its apparent diameter grows. At present the planet lies high in the southeast as morning twilight begins. When you turn your telescope on it, you'll see an ocher disk about 11″ across with a white polar cap. (It will appear not quite round because the relative geometry of Earth and Mars in their respective orbits decrees that we can see a little way past Mars' sunset terminator.) Mars is now about half as large as it will appear at opposition in late September.

Mars has weather and a day 24 hours and 37 minutes long, so viewing the Red Planet often will be rewarding. Not only does the Martian weather help you see details on the planet, but it also provides a baseline of experience from which you can detect changes easily. (For a primer


Satellites of Jupiter
9h00m UT
1 CJIG
2 CIJEG
3 CEJIG
4 CEJ
5 CGJE
6 CGJIE
7 CEGIJ
8 CEJGI
9 IJCEG
10 JIGC
11 EIJGC
12 GJEC
13 GJIEC
14 GEIJC
15 EJGIC
16 IJECG
17 JEIG
18 CEIJG
19 CGJIE
20 CGJE
21 CGEIJ
22 CEJI
23 CIJEG
24 CJEIG
25 EICJG
26 GJIC
27 GJEC
28 GEIJC
29 EGJIC
30 IJEGC
Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

on viewing Mars this opposition, see "1988: A Great Year for Mars" by Jeff Beish and Donald C. Parker, Gazer's Gazette, March 1988.)

Minor Planets

1 Ceres (magnitude 8.5) lies on the border between Aquarius and Cetus, where it rises (in mid-June) at around 2:30 a.m. Its positions:

1st: 23h54m06s, −11°32.3′
10th: 0h02m42s, −11°08.8′
20th: 0h11m07s, −10°52.9′
30th: 0h18m10s, −10°48.9′

2 Pallas (9.8) is moving slowly westward in northern Delphinus. It rises in the late evening hours and is visible until morning twilight hampers viewing. Its positions:

1st: 20h49m09s, 16°52.6′
10th: 20h47m56s, 17°35.1′
20th: 20h44m47s, 18°08.0′
30th: 20h39m52s, 18°21.8′

3 Juno is passing between Aldebaran and Orion and therefore rises too near sunrise to be found.

4 Vesta (8.1) tracks toward the southeast and moves from Cancer into Leo. Its positions:

1st: 9h05m51s, 21°44.8′
10th: 9h20m09s, 20°41.6′
20th: 9h36m34s, 19°24.2′
30th: 9h53m24s, 17°59.5′

Vesta sets by around midnight, so locate it as soon as the sky darkens after sunset.

21 Lutetia (9.9) is at opposition on June 1, and is moving westward in southern Ophiuchus, where it passes about 5-1/2° north of Antares on June 6. Its positions:

1st: 16h37m57s, −21°07.5′
10th: 16h28m41s, −21°03.1′
20th: 16h19m17s, −20°58.8′
30th: 16h12m04s, −20°58.0′

Lutetia becomes visible as the sky darkens after sunset and will set as morning twilight begins.

To locate a minor planet, photocopy the appropriate chart from a good star atlas (*Uranometria 2000.0* or *Sky Atlas 2000.0*, for example), plot the object's dated positions lightly in pencil, and sketch a smooth curve linking the points. (Positions are for 0h UT in epoch 2000.0 coordinates.) Then observe the starfield at low magnification and photograph or plot by hand what you see. Recheck the field a night or two later; the "star" that moved is the minor planet.

Jupiter

Visible in the predawn sky, Jupiter lies near the horizon early this month. However, each morning Jupiter rises a little higher until by the end of June it is about 20° above the eastern horizon, forty-five minutes before sunrise.

Because of Jupiter's low elevation, your telescopic views of Jupiter in early June will be marred by poor seeing. But from about the 15th onward, Jupiter's elevation will be sufficient to allow good viewing. In addition, you will find that prolonging your observations well into twilight will reduce the contrast between the disk and the sky and bring out more detail on the planet.

Above: Winter's evening sky gleams overhead in this all-sky photograph made by aiming a camera into a polished hubcap. Mark J. Coco used an 8mm f/2.8 lens, Fujichrome 1600D film, and a 20-minute exposure for the photograph.

Right: Bob Luffel's photograph of the Trifid Nebula in Sagittarius is this month's $100 "Best Astrophoto" award winner. Luffel made the photograph at the 1987 Riverside Telescope Makers Conference in California with a 14-inch SCT at f/7, hypersensitized Konica SR 400 film, and a 40-minute exposure.

Saturn

At opposition on June 20, Saturn is a beautiful sight as it makes its slow, day-by-day drift westward among the stars of Sagittarius. During the first week of June Saturn passes about 50′ north of M20, the Trifid Nebula. As you scan from one to the other (use a low- or medium-power eyepiece), the contrast between the zero-magnitude planet, with its hard edges and small, crisp detail, and the softly glowing and diffusely edged 7th-magnitude nebula will be striking.

On June 27, Saturn passes 1°21′ due north of Uranus, creating the second of their three conjunctions this year. (The first was on February 13, and the last will occur on October 18.) A low-power eyepiece may encompass a field large enough for you to see the two planets, but it is likely you will want to use higher magnifications on each of them individually. At high power Saturn offers details, and Uranus' small disk requires high magnification to see clearly.

Uranus

Often difficult to find amidst its crowded stellar neighborhood, Uranus is relatively easy to locate this month. In the latter half of June Uranus lies about 1.3° south of Saturn. (Uranus and Saturn are in conjunction, 1°21′ apart, on June 27.) Uranus is at opposition on June 20, the same day Saturn is, and Uranus will show a magnitude 5.5, blue-green disk some 3.8″ across. These values hold for the entire month.

Neptune

Reaching opposition on the last day of June, Neptune is at 8th magnitude and sports a blue-gray disk 2.3″ across. The planet lies in Sagittarius about 2-1/2° northeast of M22, a pretty globular cluster lying 2-1/2° northeast of 2.8 magnitude Lambda (λ) Sagittarii.

Pluto

Pluto is a difficult object to find, even for observers equipped with scopes in the 12-inch class. (A finder chart for Pluto is on page 108 of the January 1988 issue.) Locate the region of sky through which Pluto is traveling and photograph (or plot by hand) all stars down to about 15th magnitude. Recheck the area again in a few days; the 14th-magnitude dot that has drifted westward is Pluto.

— *Robert Burnham*

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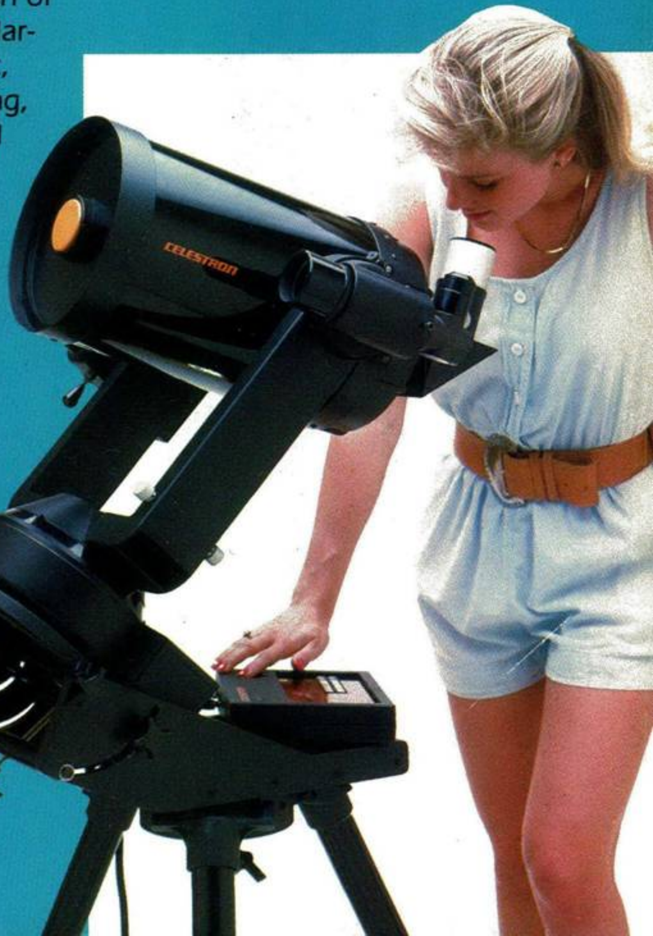

California Nebula, NGC1499, 8'' Schmidt Camera
Photo courtesy of Patrick McGuire